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Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

SUMMARIES OF CANMET ENERGY RESEARCH CONTRACTS 1979-1982

COMPILED BY T.P. LANZER

ENERGY RESEARCH PROGRAM
RESEARCH PROGRAM OFFICE

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Compiled by T.P. Lanzer

Research Program Office

100 pp

SUMMARIES OF CANMET ENERGY RESEARCH CONTRACTS 1979-1982

FOREWORD

This report summarizes contracts related to energy R & D sponsored by CANMET from 1978 to 1982. Total contract value was about $14 million, representing 12% of the total CANMET budget over the four-year period.

These summaries were prepared to assist in the transfer to industry of technology which has been gained through CANMET's extensive contracting-out program. Contracts completed prior to 1978 were summarized previously in CANMET Reports 78-1 and 79-26.

Final reports for the contracts outlined in these summaries are available through the Technology Information Division, Canada Centre for Mineral and Energy Technology (CANMET), Department of Energy, Mines and Resources, 555 Booth Street, Ottawa, Ontario, K1A 0G1; Telephone: (613)995-4029, TELEX: 053-3395.

The CANMET Program Office is grateful to Tom Lanzer of the University of Ottawa for diligently assembling this report during the summer of 1982.

D.A. Reeve
Director
Energy Program Office

AVANT-PROPOS

Le présent rapport est un sommaire des contrats liés à la R et au D en matière d'énergie que CANMET a octroyés de 1978 à 1982. La valeur globale des contrats est de 14 millions de dollars, ce qui représente 12% du budget de CANMET au cours de cette période de quatre ans.

Les présents résumés ont été préparés dans le but d'aider à transmettre à l'industrie des techniques que ont été mises au point grâce au vaste programme de sous-traitance de CANMET. Un aperçu des contrats qui ont été exécutés avant 1978 a été publié dans les rapports de CANMET n° 78-1 et 79-6.

On peut obtenir des copies définitives des rapports sur les contrats mentionnés dans le présent résumé à la Division de l'information technologique, Centre canadien de la technologie des minéraux et de l'énergie (CANMET), ministère de l'Énergie, des Mines et des Ressources, 555, rue Booth, Ottawa (Ontario) K1A 0G1. (Tél: (613) 995-4029, TÉLEX: 053-3395).

Le Bureau du Programme de recherche de CANMET tient à remercier Tom Lanzer de l'université d'Ottawa d'avoir soigneusement rassemblé les données du présent rapport au cours de l'été 1982.

Le Directeur du Programme de
recherche énergétique,
D.A. Reeve

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ENERGY TECHNOLOGY

CONSERVATION

TITLE: DEVELOPMENT OF LOW BTU GAS BURNER FOR INDUSTRIAL APPLICATION - PHASE 2

				FUNDING	
CONTRACTOR:	Canadian Gas Research Institute	FILE NUMBER:	9-9006		
		BEGIN/END:	Sept. 79/March 80		
				CANMET:	$53,868
CANMET SCIENTIFIC AUTHORITY:	G.K. Lee	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Conservation	OTHER:	--
		TECHNOLOGY:	Oil and Gas Combustion	TOTAL:	$53,868

OBJECTIVES

1. To scale up and develop burners suitable for use having low calorific value uncleaned gases based on the findings of the previous program.
2. To determine the modifications necessary to affect the flame characteristics enabling these burners to be used for a variety of industrial applications using either clean or dirty gases.
3. To apply these modifications and test their performance under a variety of conditions using a variety of low BTU gases.
4. To design a full sized industrial burner having inputs of from 120 kW to 240 kW.

PROCEDURE

1. Design gas supply system for 24 kW input.
2. Design burners based on scale up of findings from the work carried out under previous contract (Phase 1).
3. Design and construct firing chamber and burners with necessary instrumentation and gas supply system.
4. Review possible industrial applications and define types and zones of heat transfer required.
5. Prepare brief report covering designs of equipment and planned experiments and review with Scientific Authority.
6. Test measuring systems and firing chamber with regular natural gas burners and test burners in open atmosphere.
7. Test burners under various conditions, measure all necessary parameters and modify burners as required.
8. Design full sized industrial burner.
9. Prepare final report and present results at technical seminar.

RESULTS

1. The burner proved suitable for low energy gases having heating values from 3 to 6 MJ/m^3.
2. Gases having heating values below 3 MJ/m^3 will probably require the combustion air to be preheated.
3. Flame properties can be controlled by varying the ratio of primary to secondary air.
4. Swirling secondary air is desirable.
5. Spark ignition is feasible.
6. The burner produced less than 20 cm^3/m^3 carbon monoxide.
7. For typical low energy gases, the peak flame temperature was about 50°C below the adiabatic temperature.
8. Gases having high water content were burned completely.
9. The test using "dirty" gas showed that only one part of the burner may be affected by this condition.
10. A 300-kW prototype burner was designed.

APPLICATION AND ONGOING WORK

The 300-kW burner designed in Phase 2 is now being fabricated in Phase 3. When completed it will be tested at Saskatchewan Power Corporation's Hudson Bay coal gasifier facility. This burner development was planned to parallel the low-BTU coal gasification projects being undertaken under EMR's Coal Conversion and Renewable Energy Programs.

TITLE: DEVELOPMENT OF LOW BTU GAS BURNER FOR INDUSTRIAL APPLICATION - PHASE 3

				FUNDING	
CONTRACTOR:	Canadian Gas Research Institute	FILE NUMBER:	9-9147		
		BEGIN/END:	March 80/Oct. 80		
				CANMET:	$44,606
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	G.K. Lee	TECHNOLOGY:	Oil and Gas Combustion	TOTAL:	$44,606

OBJECTIVES

1. To construct a commercial size (146.5-293 kW) burner designed in Phase 2 which is suitable for use with low calorific value uncleaned fuel gases and which will have the flexibility to be used under a wide variety of applications and turn down conditions.
2. To test this burner at the Canadian Gas Research Institute using available fuels to ensure all components function as expected.
3. To arrange to test the unit at the site of a low Btu type gasifier under actual field conditions.
4. To make any needed adjustments or modifications in the field and establish the burner's performance characteristics under various gasifier operating conditions.
5. To develop complete specifications and designs for this burner which can be provided to a Canadian manufacturer for production of this equipment.

PROCEDURE

1. Review design of Phase 2 burner and make any changes deemed advisable.
2. Determine which parts can be purchased and which must be manufactured.
3. Order parts available from outside sources and manufacture parts not available outside.
4. Assemble parts after testing individual components.
5. Test fire burner using diluted methane or butane-air mixtures.
6. Modify burner in light of firing tests.
7. Fire modified burner using diluted methane or butane-air mixtures.
8. Ship burner to, and test fire burner at, gasifier site and make necessary adjustments in the field.
9. Measure various parameters when burner is optimized under different gasifier operations.
10. Prepare detailed report on design and performance including further scale up parameters.
11. Prepare a technical paper for presentation at a suitable seminar.

RESULTS

1. The scaled up burner, based on work done in Phases 1 and 2, performed successfully.
2. The burner proved suitable for low energy gases with heating values from 3 to 6 MJ/m^3 at firing rates from 150 to 300 kW.
3. Flame properties were controlled by varying the ratio of primary to secondary air.
4. The burner proved suitable for "dirty" gas.
5. Accurate setting of combustion air flows is essential for good performance.
6. Provision may have to be made for tar when designing a combustion chamber for the burner.

APPLICATION AND ONGOING WORK

Negotiations for burner design modifications to solve the tar deposition problem are underway. CGRI will submit a work statement for a proposed Phase 4 to start April 1, 1981, which will involve further field combustion trials at a gasifier producing dirty gas.

TITLE: DESIGN, MODIFICATION AND TESTING OF BURNER ASSEMBLY OF LOW BTU GAS BURNER - PHASE 4

CONTRACTOR:	Canadian Gas Research Institute	FILE NUMBER:	0-9132	FUNDING	
		BEGIN/END:	Apr. 81/March 82		
				CANMET:	$57,416
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	G.K. Lee	TECHNOLOGY:	Oil and Gas Combustion	TOTAL:	$57,416

OBJECTIVES

To resolve deterioration in burner performance when low-calorific, tar-laden gas is burned by:

1. Devising a device which would re-introduce the tar into the combustion stream and fully burn all the tar contained in the gas stream.
2. Constructing and testing this device in the laboratory with a full size burner and a synthetic tar.
3. Demonstrating the final prototype of a commercial size burner at an operational gasifier site.

PROCEDURE

1. The 300-kW burner developed in Phase 3 was operated with synthetic gas of 6 MJ/m^3 calorific value. This gas was doped with No. 6 fuel oil to simulate gasifier tar.
2. The ejected tar and its ejection pattern were measured. This led to the development of an impingement target and an annular baffle inside an extended reaction tube.
3. Tests established the optimum down stream location of the target, baffle and reaction tube for prevention of tar carryover.

RESULTS

1. The burner concept evolved proved capable of incinerating tar in concentrations up to 3L/100 kW.
2. The concept incorporates a burner cone and reaction tube fabricated from high temperature plastic refractory. This design permits sufficient re-radiation to burn methane-air mixes with calorific values of less than 4.5 MJ/m^3. Adding tertiary air causes cooling of the cone and reaction tube walls and results in lower tar incineration capacity and less re-radiation to the ignition zone of the burner.
3. The burner assembly, including the reaction tube, was tested at firing rates from 370 kW to 260 kW (1.24×10^6 to 0.89×10^6 Btu/h) with no evidence of malfunction.
4. In developing commercial prototypes of the burner, provision will have to be made for control systems capable of igniting low Btu gasifier gas, flame sensing and controlling the flow of tar-laden fuel.

APPLICATION AND ONGOING WORK

Project terminated. Patent search requested to evaluate feasibility of patent application by CGRI and CANMET. CGRI will act as the vehicle for technology transfer should a burner of this type be required to burn the output from coal or biomass gasifiers.

ENERGY TECHNOLOGY

PETROLEUM SUPPLY

TITLE: DEVELOPMENT PROGRAM OF THE MAGNA TAR SAND EXTRACTION PROCESS

CONTRACTOR:	Magna International Inc.	FILE NUMBER:	8-9002	FUNDING	
		BEGIN/END:	June 78/Dec. 79		
				CANMET:	$280,000
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	335,000
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	D.K. Faurschou	TECHNOLOGY:	Bitumen/Heavy Oil Recovery	TOTAL:	$615,000

OBJECTIVES

1. Generate scientific, technical and engineering data required for a sub-contracted technical/economic assessment of the Magna process projected to a commercial scale and required for design of a demonstration-scale plant.

2. Independent assessment of the Magna process as a basis for further development, preferably on a joint venture basis between Magna and industry.

3. Secure patent coverage.

PROCEDURE

1. Continue development and operation, on a pilot-plant scale, of the Magna cold water/solvent process for separation of bitumen from Athabasca oil sand.

2. Sub-contract to Hycarb and to In-Situ Engineering the independent economic/technical assessment of the Magna process.

RESULTS

1. The technical feasibility of the Magna process was established with significant advantages in energy utilization, environmental impact, water utilization and oil sand resource management over the conventional hot water process.

2. On a Syncrude-size scale, the discounted rate of return should be increased for the Magna versus the hot water process.

3. The Magna process is compatible with thermal hydrocracking on an energy account basis.

4. The consultants recommended proceeding to a demonstration stage.

5. Several patents have been issued to Magna.

APPLICATION AND ONGOING WORK

With existing commercial technology the number of surface oil sand plants will be restricted severely due to shortage of water supplies and environmental impacts. The Magna process would permit significantly greater exploitation of surface mineable oil sands.

The consultants' report and Magna's own final contract report are being used by Magna to develop interest in potential partners for joint venture development of this process.

TITLE: DEMULSIFICATION OF BITUMEN-WATER EMULSION PRODUCED BY IN SITU RECOVERY

				FUNDING	
CONTRACTOR:	University of Western Ontario	FILE NUMBER:	8-9065-1		
		BEGIN/END:	Apr. 80/Sept. 80		
				CANMET:	$60,305
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	H. Sawatzky	TECHNOLOGY:	Bitumen/Heavy Oil Recovery	TOTAL:	$60,305

OBJECTIVES

1. To prepare sufficient quantities of bacterial products that had been developed for a preceding contract and that had been found effective for water/kerosene emulsion breaking so that they could be tested for demulsification of bitumen/water emulsions, as well as several emulsions obtained during uranium recovery.

2. To determine the heat and storage stability of these bacterial products, as well as of the biological surfactants that had to be developed for bitumen extraction. If heat and storage stabilities could be achieved, to produce 5 large (20 L) batches for testing in the Alberta Research Council facilities for use in bitumen extraction.

3. To obtain relevant basic data.

PROCEDURE

Broths of certain hydrocarbon metabolizing bacteria were produced for obtaining the products that had been found to be the most effective for demulsification of water/kerosene emulsions.

These broths were used as such, or the bacterial bodies were isolated for use in emulsion breaking.

Tests were made to determine the effect of heat and storage.

RESULTS

The bacterial products were prepared for testing their emulsion breaking capabilities on several bitumen/water emulsions, as well as on emulsions from uranium extraction operations, but were found to be ineffective.

These bacterial products, as well as surfactants developed earlier, could be rendered stable using preservatives.

The bacterial products were produced in large amounts and delivered to the Alberta Research Council for hot pot bitumen extraction tests.

A patent was applied for in connection with breaking stable kerosene/water emulsions. Unfortunately, the hot pot tests at Alberta Research showed no significant improvement for bitumen/sand separation.

TITLE: HYDRAULIC CUTTING TESTS ON OIL SANDS

CONTRACTOR:	University of Alberta	FILE NUMBER:	8-9123	FUNDING	
		BEGIN/END:	Apr. 79/March 80	CANMET:	$16,958
CANMET SCIENTIFIC AUTHORITY:	L. Geller	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
		TECHNOLOGY:	Bitumen/Heavy Oil Recovery	TOTAL:	$16,958

OBJECTIVES

To test the hydraulic cutting of oil sands in the field.

PROCEDURE

1. Design and manufacture the relevant hydraulic jet-cutting device. Move equipment into field and run tests on tar sand deposits.
2. Report results.

RESULTS

1. The undisturbed oil sands deposits in the field were, in general, easier to cut than reconstituted laboratory samples.
2. Scaling equations, previously developed in the laboratory, were found to be applicable to field cutting rates.
3. Water required for hydraulic cutting is less than the amount needed for their processing.
4. Specific energy requirements are in the order of 10 MJ/m^3, which is acceptable.

APPLICATION AND ONGOING WORK

No ongoing work. Possible application to hydraulic bore-hole drilling in tar sands.

TITLE: OPTIMUM APPLICATION OF COAL AS AN ENERGY AND HYDROGEN SOURCE IN OIL RECOVERY FROM BITUMEN SANDS - PHASE 2

CONTRACTOR:	In-Situ Research & Engineering Ltd.	FILE NUMBER:	7-9105	FUNDING	
		BEGIN/END:	June 78/Dec. 79	CANMET:	$49,540
CANMET SCIENTIFIC AUTHORITY:	R. Ranganathan	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
		TECHNOLOGY:	Bitumen/Heavy Oil Refining	TOTAL:	$49,540

OBJECTIVES

Comparison of EMR Thermal Hydrocracking Process with Flexicoking for various processing schemes to upgrade Athabasca and Cold Lake bitumen. In Phases 1 and 2, a total of 14 cases were evaluated and compared.

PROCEDURE

Capital and operating estimates were made for each processing scheme and economics of each scheme were calculated. Comparisons were made using the economic programs developed by In-Situ Research and Engineering Limited.

RESULTS

The EMR Thermal Hydrocracking Process was competitive to commercial Flexicoking processes. In general, the EMR process was found to be superior.

APPLICATION AND ONGOING WORK

Being used in development activities of the CANMET Hydrocracking Process to assist in economic evaluations.

TITLE: SOLUBILITY OF HYDROGEN AND HYDROGEN SULPHIDE IN BITUMEN AND HYDROCRACKED PRODUCTS

CONTRACTOR:	University of Alberta	FILE NUMBER:	8-9038	FUNDING	
		BEGIN/END:	July 78/March 79	CANMET:	$11,882
CANMET SCIENTIFIC AUTHORITY:	R. Ranganathan	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
		TECHNOLOGY:	Bitumen/Heavy Oil Refining	TOTAL:	$11,882

OBJECTIVES

To measure solubilities of hydrogen and hydrogen sulphide gas in bitumen and hydrocracked products at various temperatures and pressure.

PROCEDURE

A high pressure batch autoclave system with GC facilities for measuring gases was used.

RESULTS

Data for solubilities of hydrogen and hydrogen sulphide gases were obtained for up to 15 MPa pressure and up to 370°C. Data could only be obtained up to 370°C, because at higher temperatures cracking occurred.

APPLICATION AND ONGOING WORK

These data will be useful for design of units for high pressure hydrocracking processes. Additional work is being done during 1979/80 to obtain data for coal/bitumen slurries.

TITLE: CHEMICAL CHARACTERIZATION OF PITCH

CONTRACTOR:	Beak Consultants Ltd.	FILE NUMBER:	9-9108	FUNDING	
		BEGIN/END:	July 80/Jan. 81		
				CANMET:	$47,957
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	A. George	TECHNOLOGY:	Characterization of Bitumen/Heavy Oils	TOTAL:	$47,957

OBJECTIVES

To investigate the chemical composition of pitch produced from Athabasca and Cold Lake bitumens, and from Lloydminster heavy oil for ultimately relating the coking propensities of these pitches to chemical composition.

PROCEDURE

1. Distillation and deasphaltening.
2. Quantitative separation of the "acids", "bases" and neutral nitrogen compounds on ion-exchange resins.
3. Quantitative separation of the unreactive maltenes to hydrocarbon-component type.
4. Analysis of the various fractions by infrared spectroscopy.
5. Elemental analysis and molecular weight determinations.

RESULTS

1. Athabasca bitumen was the only pitch having a detectable ash content and this was analyzed for metal content (V, Ni, Fe). Sulphur content was about 5.6% for all three pitches indicating the need for desulphurization prior to upgrading. The N content of 0.7% could lead to N poisoning of catalysts used in upgrading.
2. Of the three non-polar solvents used for the initial separation into maltenes and asphaltenes, n-pentane, the solvent with the smallest molecule, gave the largest amount of asphaltene (39.5% to 36.7%).
3. Results obtained using n-heptane and n-decane were very similar and do not justify the use of n-decane. The molecular weights of both fractions increased using n-heptane and n-decane indicating the solubilization by the higher molecular solvent of the lower end of asphaltene fraction into the maltene fraction. The liquid chromatography methods applied for maltene separation proved to be adequate; good reproducibility and mass balances were obtained over all steps.
4. The results of the chromatographic separation of maltenes indicated a higher content (20% greater) of heteroatomic compounds of the acid and base type in the Athabasca pitch.
5. The polynuclear aromatic fraction was found to be predominant in all three pitches representing between 21.1% in Cold Lake and 33.6% in Lloydminster.
6. The molecular weight of the heteroatomic type fractions was considerably higher than that of the hydrocarbon fractions.
7. Elemental analysis of the fractions indicated a concentration of nitrogen and oxygen compounds in acid and base fractions; sulphur was evenly distributed in the acid, base, neutral nitrogen, diaromatic and polyaromatic polar fractions, having values generally over 3% *m/m*.
8. The saturate and monoaromatic hydrocarbon fractions are the only ones with a very low sulphur content (<0.05%). For all three pitches the saturate and monoaromatic hydrocarbon fractions showed a reduced content of heteroatoms (O, N and S).
9. Major types of compounds identified by IR methods were found to be as follows: carboxylic acids, phenols, carbazoles and amides in the acid fractions; pyridine benzologs, amides and pyrrolic compounds in the base fractions and amides and pyrrolic compounds in the neutral nitrogen.
10. The hydrocarbon fractions were found to be of predominantly naphthenic character, with a strong paraffinic presence in the saturate, mono and diaromates.
11. About 20% of the carbons present in the polyaromatic-polar fraction were aromatic and 70-75% naphthenic. Only 4-8% of the carbons in this fraction were found to be of paraffinic nature.

APPLICATION AND ONGOING WORK

Further work will be contracted out for various pitch samples (hydrocracked products of bitumens and heavy oils as well as feedstocks) that showed different affinities as binders in making metallurgical coke.

Since the chemical differences between the pitches are not conspicuous, a more detailed analytical scheme will be used for further work.

TITLE: ASSESSMENT OF POTENTIAL OF SYNTHETIC CRUDE FOR THE MANUFACTURE OF STANDARD REFINERY PRODUCTS

CONTRACTOR:	Imperial Oil Enterprises Ltd.	FILE NUMBER:	8-9021	FUNDING	
		BEGIN/END:	Nov. 78/July 79		
				CANMET:	$28,355
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	C.P. Khulbe	TECHNOLOGY:	Upgrading of Synthetic Crudes to Transportation Fuels	TOTAL:	$28,355

OBJECTIVES

The synthetic crude obtained by hydrocracking of Athabasca bitumen could be processed in a conventional refinery. There could be different combinations of existing facilities. A detailed slate of the products and yields which could be obtained from the synthetic crude will be a guide to process this feed economically for its best use.

PROCEDURE

Detailed crude assay:

1. Distillation into narrow cuts.
2. Analysis of different cuts.
3. Compute properties of refinery feedstocks.
4. Assess the quality, potential and deficiencies of cuts.
5. Predict yields of different refinery units based on computer simulation.
6. Compare with other synthetic crude.

RESULTS

The CANMET product is a sour, medium gravity, low pour point material. It contains small volumes of olefinic motor gasoline components, large volumes of aromatic middle distillates and a large volume of catalytic cracker feed. A severe hydrotreating of the product is required to produce acceptable reformer, turbo and diesel fuels. Because of the highly aromatic nature of the catalytic cracker feed fraction, coke burning capacity of a catalytic cracker would limit the conversion to gasoline components. A pilot plant program would be necessary to determine the optimum operating conditions for hydrotreating to meet the appropriate specifications.

APPLICATION AND ONGOING WORK

Hydrotreating of the products and evaluation of the hydrotreated synthetic crude produced from other heavy oils and bitumen.

TITLE: METHODOLOGY FOR AN INTEGRATED ANALYSIS OF THE MATERIALS-RELATED ASPECTS OF RELIABILITY IN LOAD-BEARING COMPONENTS OF LARGE-SCALE ENGINEERING STRUCTURES

				FUNDING	
CONTRACTOR:	Tektrend International Ltd.	FILE NUMBER:	8-9046		
		BEGIN/END:	Oct. 78/Dec. 80		
				CANMET:	$ 52,380
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER (DSS):	68,980
AUTHORITY:	O. Vosikovsky	TECHNOLOGY:	Materials for Oil and Gas Pipelines	TOTAL:	$121,360

OBJECTIVES

1. To develop methodology for an integrated analysis of the materials related aspects of reliability of large scale engineering structures.
2. To implement the methodology in optimization of inspection procedures of pipelines in a series of demonstration runs.
3. To provide documented computer programs.

PROCEDURE

1. Review literature, consult with industries and regulatory agencies.
2. Select input elements for the model.
3. Prepare computer programs for implementation of the model in application to pipelines.
4. Optimize inspection intervals and level for single and multiple inspections, and for selected material degradation mechanism, with regard to reliability and cost.
5. Recommend procedures to improve the use of inspection data in pipeline reliability estimates.

RESULTS

1. Phase 1 report outlines the methodology for optimization of inspection procedures. The developed probabilistic model uses as inputs:
   a) initial distribution of defects,
   b) probability of non-detection of a defect by the used inspection technique, and
   c) growth law of the defect by particular degradation mechanism.
2. Phase 2 report demonstrates use of the model by analyzing real inspection data from an existing oil pipeline. Future inspection intervals are optimized for corrosion pitting degradation mechanism and procedures for better utilization of inspection data are recommended.
3. The documented computer programs used for inspection optimization have been provided.

APPLICATION AND ONGOING WORK

Information obtained provides the basis for quantitative estimates of pipeline reliability and optimization of inspection procedures regarding reliability and cost. It also provides an analytical tool for determination of sensitivities of inspection techniques resulting in maximum reliability. This information is valuable for pipeline operators and regulatory agencies.

TITLE: DYNAMIC TOUGHNESS TESTING OF STEEL - PHASE 2

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	8-9145	FUNDING	
		BEGIN/END:	May 79/March 80		
				CANMET:	$ 8,480
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	38,000
AUTHORITY:	L.P. Trudeau	TECHNOLOGY:	Materials for Oil and Gas Pipelines	TOTAL:	$46,480

OBJECTIVES

To enable Ontario Research Foundation (ORF) to determine the reliability and usefulness of their instrumented drop-weight test equipment and to transfer to ORF technology on dynamic testing.

PROCEDURE

The output from the commercial test equipment was studied as a function of specimen design and toughness and was compared with the output from instrumentation on the specimens.

RESULTS

Increased understanding of dynamic testing and the limitations inherent in the equipment which result from high frequency oscillations in the instrumented impact trip.

APPLICATION AND ONGOING WORK

The results are applicable to the assessment of steel toughness for pipelines, ships, bridges, and other structures. The ORF has a contract with Foothills Pipeline Co. to assess steel toughness.

TITLE: EFFECT OF MOLYBDENUM AND NIOBIUM ON THE HOT WORKING OF LINEPIPE STEELS - PHASE 2

CONTRACTOR:	McGill University	FILE NUMBER:	8-9143	FUNDING	
		BEGIN/END:	May 79/March 80		
				CANMET:	$29,903
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.E. Ruddle	TECHNOLOGY:	Materials for Oil and Gas Pipelines	TOTAL:	$29,903

OBJECTIVES

To determine the effect of microalloying elements Mo, Nb and V on the precipitation and recrystallization rates in controlled rolling to enable HSLA alloy design (and roll pass scheduling) to be carried out more rationally, and with less trial and error.

Phase 2: In the 2nd contract year, the investigation will be continued at moderate strain rates on the McGill Instron-based compression machine to establish the effect of microalloying elements in solution on the recrystallization kinetics and to determine the precipitation kinetics. Experiments in the range of plate rolling strain rates (~5/s) will be carried out on the MTS-based compression machine to determine the solute and precipitate effects under simulated industrial conditions.

PROCEDURE

Hot compression tests were completed on four of nine experimental steels selected for investigation of the effects of Nb, V, Mo and Mn, singly and in various combinations, on the rate of austenite recrystallization. The distinctive compositions of the four tested steels were:

0.06 C-1.43 Mn (reference steel)
0.05 C-1.25 Mn-0.035 Nb
0.06 C-1.90 Mn-0.035 Nb
0.05 C-1.25 Mn-0.115 V

Machined test specimens were given controlled normalizing and austenitizing treatments prior to testing. Compression tests were performed isothermally at 925, 900 and 875°C and at constant strain rates in the range 10^{-5} to 1 s^{-1}. Peak strains (times) associated with the start of dynamic recrystallization were measured from the true stress-true strain curves produced in the tests. From the strain rate and temperature dependence of the peak strains, precipitation-temperature-time curves for dynamic precipitation of Nb(CN) and VN were determined.

Compression testing under the same strain rate and temperature conditions was started on another two of the selected steels:

0.05 C-1.2 Mn-0.035 Nb-0.115 V
0.05 C-1.3 Mn-0.035 Nb-0.3 Mo

These tests combined with testing of the three remaining steels:

0.05 C-1.3 Mn-0.3 Mo
0.05 C-1.3 Mn-0.3 Mo-0.1 V
0.05 C-1.3 Mn-0.3 Mo-0.1 V-0.035 Nb

will be completed in Phase 3 of the contract. Experimental tests in the range of plate rolling strain rates on the hot torsion machine also were started and will be completed in Phase 3.

RESULTS

An increase in Mn level from 0.42 to 1.9% in the Nb-bearing steel delays the start of dynamic precipitation of Nb(CN) by more than one order of magnitude, e.g., from 0.6 to 24 s at 900°C. This effect is associated with decreased C activity and increased solubility of Nb(CN) caused by addition of Mn. A similar effect of Mn on the precipitation of VN has been reported.

The precipitation kinetics for Nb(CN) and VN, as well as AlN, are broadly similar at equivalent Mn levels.

There is a much greater influence of Nb than of V, as solute, on retardation of austenite recrystallization. This difference in solute effect, rather than differences in precipitation behaviour, is linked to the greater effectiveness of Nb in promoting pancaking of austenite during controlled rolling. The difference in effectiveness of the solutes is attributed primarily to differences of electronic structure, and secondarily to differences of atomic size, relative to Fe.

The yield strength of austenite at 875-900°C is increased by about 1.3, 7 and 70% respectively per 0.1 atomic % of Mn, V and Nb in solution.

At roughing temperature (above 925°C), when recrystallization goes to completion between rolling passes in both plain C and microalloyed steels, differences in rolling load are largely attributed to the direct influence of alloying elements in solution on the yield stresses. During finishing (below 925°C), differences in rolling load are primarily attributed to the effect of alloying elements, in solution and as precipitate formers, in retarding the rate of recrystallization.

APPLICATION AND ONGOING WORK

The contract work has been continued into the third of three proposed phases.

TITLE: EFFECT OF MOLYBDENUM AND NIOBIUM ON THE HOT WORKING OF LINEPIPE STEELS - PHASE 3

CONTRACTOR:	McGill University	FILE NUMBER:	9-9126	FUNDING	
		BEGIN/END:	Apr. 80/June 81		
				CANMET:	$37,144
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.E. Ruddle	TECHNOLOGY:	Materials for Oil and Gas Pipelines	TOTAL:	$37,144

OBJECTIVES

To determine the effect of microalloying elements Mo, Nb and V on the precipitation and recrystallization rates in controlled rolling, to enable HSLA alloy design (and roll pass scheduling) to be carried out more rationally, and with less trial and error.

Phase 3: In the 3rd contract year, the investigation will be continued at moderate strain rates on the McGill Instron-based compression machine to establish the effect of microalloying elements in solution on the recrystallization kinetics. Experiments in the range of plate rolling strain rates (~5/s) will be carried out on the MTS-based torsion machine to determine the solute and precipitate effects under simulated industrial conditions.

PROCEDURE

Hot compression tests were completed on the remaining five of nine experimental steels selected for studying the effects of Nb, V, Mo and Mn, singly and in various combinations, on the rate of austenite recrystallization. The composition of the five tested steels were:

0.05 C-1.2 Mn-0.035 Nb-0.115 V
0.05 C-1.3 Mn-0.035 Nb-0.3 Mo
0.05 C-1.3 Mn-0.3 Mo
0.05 C-1.3 Mn-0.3 Mo-0.1 V
0.05 C-1.3 Mn-0.3 Mo-0.1 V-0.035 Nb

The compositions of the four steels on which tests were completed in the previous work phases were:

0.06 C-1.43 Mn (reference steel)
0.05 C-1.25 Mn-0.035 Nb
0.06 C-1.90 Mn-0.035 Nb
0.05 C-1.25 Mn-0.115 V

Machined test specimens were given controlled normalizing and austenitizing treatments prior to testing. Compression tests were performed isothermally at 925, 900 and 875°C and at constant strain rates in the range 10^{-5} to 1 s^{-1}. Peak strains (times) associated with the start of dynamic recrystallization were measured from the true stress-true strain curves produced in the tests. From the strain rate and temperature dependence of the peak strains, precipitation-temperature-time curves for dynamic precipitation of Nb(CN) and VN were determined. The compression testing was extended to determine dynamic recrystallization start times up to 1150°C.

Hot torsion testing of the steels was completed to determine solute effects in the range of plate rolling strain rates, up to 5 s^{-1}.

RESULTS

Summary of Phases 1-3.

The order of effectiveness of the microalloying elements, singly and in combination, as solutes and precipitates, on yield strength and on retardation of recrystallization under hot working conditions was established.

Single additions of Nb, Mo, V and Mn, as solutes, increase hot yield strength with respect to the reference steel by amounts of 70, 9, 7 and 1.3% respectively, per 0.1 atomic % of addition. The effect of combined additions is larger than the sum of the individual strengthening increments. The relative influence of the addition elements was interpreted, basically in relation to the periodic series, in terms of the magnitudes of their atomic size and electronic valence differences with respect to γ-iron.

The influence of single additions of the microalloying elements, in solution, on the retardation of dynamic recrystallization is greatest for Nb, followed by Mo and V. Retardation by combined additions of these elements is less than the sum of the individual effects. Additions of Mo or higher Mn retard the austenite precipitation of Nb(CN) and VN, and increase the propensity for precipitation in the ferrite phase. The relative order of influence of the microalloying elements on retardation of dynamic recrystallization applies at temperatures below and above the level for solution of the carbonitrides. The "no-recrystallization" temperatures (or "austenite-pancaking" temperatures in terms of controlled rolling) were determined semi-quantitatively from the dynamic recrystallization kinetics. This temperature was highest for the Nb-V-Mo steel, followed by the Nb-Mo, Nb-V, Nb-high Mn, V-Mo, Mo, and V steels.

APPLICATION AND ONGOING WORK

Information obtained will be used to design steel composition and roll pass scheduling in related CANMET research and in Canadian production of steel strip, plate and linepipe.

New contract research has started on the microalloying effects of Ti, singly and in combination with Nb and Mo, on hot working.

TITLE: EFFECTS OF MOLYBDENUM, TITANIUM, AND NIOBIUM ON THE HOT WORKING (CONTROLLED ROLLING) OF LINEPIPE STEELS - PHASE 1

CONTRACTOR:	McGill University	FILE NUMBER:	0-9171	FUNDING	
		BEGIN/END:	June 81/March 82		
				CANMET:	$52,000
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.E. Ruddle	TECHNOLOGY:	Materials for Oil and Gas Pipelines	TOTAL:	$52,000

OBJECTIVES

To conduct experimental research to determine the effects of microalloying elements Mo, Nb and Ti on the rates of recrystallization, grain growth and precipitation in terms of controlled rolling practice of high-strength linepipe-grade steels, to reduce microalloying costs and improve steel properties.

Phase 1: Effects of single microalloying additions: study the effects of single microalloying additions of Mo, Nb and Ti, and of Mo and Nb in combination, on the hot deformation of austenite.

PROCEDURE

Hot compression testing was completed on three 0.1% Ti steels with Mn levels of 0.5, 1.1 and 1.6%. Prior to testing, machined test specimens were vacuum-annealed at 1000°C for 2 h and quenched to eliminate rolling texture; subsequently they were austenitized in argon at 1260°C for 30 min and cooled to test temperature. Initial austenite grain sizes resulting from this treatment were 110-120 μm. Compression tests were conducted isothermally between 925-1225°C and at strain rates in the 10^{-5} to 1 s^{-1} range.

Dynamic recrystallization-temperature-time and precipitation-temperature-time kinetics were determined for the Ti steels and compared with the kinetics for plain carbon, V, Mo and Nb steels.

RESULTS

Increasing the Mn level in the 0.1% Ti steels decreases the TiC precipitate solution temperature, and therefore delays the start of precipitation during austenite deformation. This result is similar to the retarding effect of Mn on Nb(CN) precipitation in austenite arising from a decrease in the activity coefficients of C and N. However, even at the highest Mn level (1.6%), TiC precipitation starts at high temperature and short time from start of deformation; e.g., 7 s at 1025°C and .028 s^{-1} strain rate, compared with the kinetics of Nb(CN) and VN precipitation.

Comparison of the solute effect of Ti with other microalloying elements on the retardation of recrystallization during austenite deformation shows that Ti at the 0.1% level is slightly more effective than 0.035% Nb. Beginning at 1075°C, TiC precipitation further retards dynamic recrystallization. However, ranking of microalloying effectiveness on an equal atom fraction basis places Nb ahead of Ti.

APPLICATION AND ONGOING WORK

For CANMET and Canadian industrial development of thermomechanical processes using Ti-bearing steels, e.g., strip for light gauge tubing, conventional gauge plate for linepipe, and heavy gauge plate for linepipe and marine applications.

TITLE: DESIGN, FABRICATION AND TESTING OF ULTRASONIC SCANNER CAPABLE OF MEASURING THE DEPTH OF FATIGUE CRACK AT TOE OF LONGITUDINAL WELD IN CRUDE OIL PIPELINE

CONTRACTOR:	Welding Institute of Canada	FILE NUMBER:	9-9070	FUNDING	
		BEGIN/END:	March 80/Feb. 81	CANMET:	$29,913
CANMET SCIENTIFIC AUTHORITY:	O. Vosikovsky	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
		TECHNOLOGY:	Materials for Oil and Gas Pipelines	TOTAL:	$29,913

OBJECTIVES

1. To design, fabricate and test an ultrasonic scanner capable of measuring the depth of fatigue cracks at the toe of a longitudinal weld in a crude oil pipeline with an accuracy better than ±0.5 mm.

2. Using the ultrasonic scanner, to verify predicted corrosion fatigue life of a sour crude oil pipeline on a full size model test.

PROCEDURE

1. Design and fabricate a UT scanner based on the time of flight technique and calibrate the scanner on natural cracks and artificially introduced defects in a segment of linepipe.

2. Use the scanner to monitor the growth of weld-toe corrosion fatigue cracks during spectrum cyclic pressure tests of full size linepipe, pressurized with crude oil containing ~100 ppm of hydrogen sulphide.

RESULTS

1. The UT scanner has been successfully developed and tested.

2. The second phase of the contract failed to produce expected results due to circumstances beyond the control of the contractor. (The model pipe, cut out of the failed pipeline, did not contain initial weld-toe cracks. The outdoor experiments were delayed because of several failures of testing equipment and as a result low and variable winter temperatures interfered with the accuracy of the ultrasonic measurements). The follow-up contract has been awarded for new tests with artificially introduced defects.

APPLICATION AND ONGOING WORK

The contract is part of a joint CANMET-Interprovincial Pipeline Co. project on prediction of corrosion fatigue lives of sour crude oil pipelines containing weld defects. The project will provide means for calculating acceptable defect sizes for expected pipeline life. The results will help pipeline operators and regulatory bodies to improve safety of crude oil pipelines.

TITLE: ULTRASONIC MONITORING OF CRACK EXTENSION BY CORROSION FATIGUE IN OIL PIPELINES

CONTRACTOR:	Techno Scientific Inc.	FILE NUMBER:	0-9169	FUNDING	
		BEGIN/END:	July 81/Dec. 81	CANMET:	$17,865
CANMET SCIENTIFIC AUTHORITY:	O. Vosikovsky	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
		TECHNOLOGY:	Materials for Oil and Gas Pipelines	TOTAL:	$17,865

OBJECTIVES

To monitor the growth of fatigue cracks in three full-size linepipe tests. The tests are designed to simulate the actual operation of a sour crude oil pipeline, i.e., crude oil with 100 ppm of hydrogen sulphide is used as a pressure medium and a condensed pipeline pressure history is used as a loading spectrum.

The main objective of the tests is to verify the fracture mechanics predictions of corrosion fatigue life of a pipeline.

PROCEDURE

1. Introduce artificial defects of specified dimensions along the longitudinal weld of the test pipes.
2. Fatigue the test pipes with a specified pressure spectrum until the pipe leaks or breaks.
3. Using the ultrasonic scanner developed in the previous contract, periodically monitor the extensions of fatigue cracks, growing from initial defects.

RESULTS

The contract has been successfully completed. The results of the full-scale tests verified the choice of parameters in fracture mechanics methodology for prediction of corrosion fatigue life of sour crude oil pipelines, developed within the CANMET project "Characterization of Weld Defects".

APPLICATION AND ONGOING WORK

The developed fracture mechanics methodology will be used by Interprovincial Pipe Lines (which participated in the project) and other crude oil pipeline operators for calculating the acceptable defect sizes. The realistic inspection criteria will improve the reliability and safety of crude oil pipelines.

TITLE: REVIEW OF STEELS USED IN CONSTRUCTION OF OFFSHORE STRUCTURES

CONTRACTOR:	Det Norske Veritas (Canada) Ltd.	FILE NUMBER:	1-9046	FUNDING	
		BEGIN/END:	Oct. 81/Jan. 82		
				CANMET:	$36,413
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	J.B. Gilmour	TECHNOLOGY:	Materials for Oil and Gas Pipelines	TOTAL:	$36,413

OBJECTIVES

To prepare a review of specifications used by various regulatory agencies, classification societies and others for the steels and weldments used in constructing offshore structures. Particular attention was to be given to the relationship between fracture properties and minimum service temperature.

PROCEDURE

Reviewed regulations, recommendations and guidelines issued by:

- Norwegian Petroleum Directorate
- U.K. Department of Energy
- U.S. Geological Survey
- Det Norske Veritas
- Bureau Veritas
- Germanischer Lloyd
- Lloyd's Register
- American Bureau of Shipping
- Nippan Kaiji Kyokai
- American Petroleum Institute
- American Welding Society
- American Society for Mechanical Engineers

RESULTS

The review indicates that the rules used elsewhere relating minimum service temperature and fracture properties probably can be applied to developments off Canada's east coast. However, Arctic conditions are such that the application of "normal rules" would require fracture properties which cannot normally be obtained with structural steels at very low temperatures.

APPLICATION AND ONGOING WORK

Background information for "Materials for Offshore Structures" project.

ENERGY TECHNOLOGY

COAL

TITLE: QUALITY AND OCCURRENCE OF COAL IN SOUTHERN SASKATCHEWAN

CONTRACTOR:	Saskatchewan Research Council	FILE NUMBER:	8-9015	FUNDING	
		BEGIN/END:	Aug. 78/June 79	CANMET:	$52,131
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	T.E. Tibbetts	TECHNOLOGY:	Resource & Reserve Assessment	TOTAL:	$52,131

OBJECTIVES

1. To compile facts to help correlate analytical properties of lignite with specific coal seams in Saskatchewan.

2. To prepare a report on the quality and occurrence of coal in southern Saskatchewan.

PROCEDURE

Demonstrate the methodology of data acquisition and the application of computer processable files for assessment of quality and occurrence of coal.

RESULTS

Report: Volume I: Introduction to Data Acquisition and to Associated Computer Processable Files.

TITLE: PROTOTYPE DESIGN OF A FLAMEPROOF EXHAUST SYSTEM FOR DIESEL ENGINES USED IN UNDERGROUND COAL MINES

CONTRACTOR:	University of British Columbia	FILE NUMBER:	8-9087	FUNDING	
		BEGIN/END:	Apr. 79/March 80		
				CANMET:	$10,914
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mining	TOTAL:	$10,914

OBJECTIVES

To design an improved flameproof diesel exhaust system incorporating an exhaust cooler and a "hot" reduced maintenance flame trap in advance of an optional water scrubber.

PROCEDURE

1. The appropriate equipment was selected which included a water cooled flameproof diesel engine (Caterpillar #3304) and a J. Kyle Gardner approved plate type flame trap.

2. A design for an exhaust cooler was undertaken to reduce exhaust gas temperature to 149°C.

3. Suitability of the turbocharged version of the radiator for handling the increased exhaust cooling duty associated with the normally aspirated machine was determined.

4. Additional suggestions for cooling the exhaust gas below 149°C by induced dilution were made.

RESULTS

Although the initial contract called for delivery of the hardware, this was not possible because overloading in the University machine shop prevented fabrication. Consequently, the contract was reduced from $15,000 to $10,914 for the design only.

The design is outlined in the report. The highlights are:

1. The standard Caterpillar turbocharged radiator version proved adequate for the additional cooling load imposed by the 149°C exhaust temperature maximum limit.

2. The heat exchanger design dimensions were 324 mm O.D. x 1.5 m and the gas side pressure drop was estimated to be 125 mm H_2O, gauge, indicating the feasibility of this cooling approach.

3. Air induction can be used to cool the exhaust to 71°C without addition of water.

Subsequent to this work, a cooler has been designed by Hovey and Associate which is more compact and has a gas side loss of 150 mm H_2O.

APPLICATION AND ONGOING WORK

This design work was a preliminary step establishing the feasibility, from a thermal point of view, of exhaust cooling and the use of a hot flame trap. This work will be carried on in 1981/82 by Kaiser Resources using the Hovey cooler in a Caterpillar-powered Wagner ST5 LHD machine for practical trials underground.

TITLE: ASSESSMENT OF CRITERIA FOR IGNITION OF METHANE/COAL DUST BY FRICTIONAL OR IMPACT HEATING OF DIESEL EQUIPMENT

CONTRACTOR:	University of British Columbia	FILE NUMBER:	8-9108	FUNDING	
		BEGIN/END:	May 79/May 80		
				CANMET:	$15,000
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mining	TOTAL:	$15,000

OBJECTIVES

To evaluate the risk of ignition of methane/coal dust/air atmospheres and/or coal dust layers as applicable, by frictional and impact heating of:

1. Abnormal operation of disc brakes.

2. Air starter engagement of pinion on ring-gear such as normally occurs on start-up of mobile diesel-powered mining equipment.

PROCEDURE

1. Enclose both brake (friction) and starter (impact) simulating systems in explosive atmospheres of methane/coal dust/air.

2. Operate these model systems as similarly as possible to the operation of the full-scale or actual mine vehicle systems, constantly or repetitively as the case may be, and note the relevant operating conditions and whether inflammation of the explosive mixtures occurs.

RESULTS

A - DRAGGING BRAKE FRICTION

1. Conventional disc brake linings attain temperatures of 400°C (+10-70) (752°F) after 15 min of operation for a maximum power dissipation of 0.347 kW/cm^2 (3.0 hp/in.^{2}) of brake pad area.

2. Coal dust bearing surfaces, such as the calipers, attain temperatures of 170°C (+0-50) (338°F) after 15 to 20 min operating at the same power dissipation level. A 5-mm layer of DEVCO high-volatile coal did not inflame during one such test.

3. The use of commercial lining materials at elevated ambient, lining and caliper temperatures in explosive methane/coal dust/air mixtures near the lean limit, did not result in inflammation when power dissipation ratios of up to 0.347 kW/cm^2 (3.0 hp/in.^{2}) of brake lining were applied.

4. The use of lean methane mixtures, failure to sample the coal dust mixtures and inadequate consideration of the model to full-scale relationships suggest that work such as this should be done within MRL's Canadian Explosive Atmospheres Laboratory because remote monitoring is not feasible to the extent needed to avoid such inadequacies.

B - STARTER IMPACT

1. No ignition of CH_4/coal dust/air mixtures (7.76% CH_4 max) occurred as a result of 50 starter operations of the steel pinion of an air-operated Bendix type starter with the hardened cast iron ring gear; 6 of these engagements were dead-end tooth-to-tooth impacts.

2. These tests suggest that the starter system is safe from a tooth-to-tooth direct impact point of view.

APPLICATION AND ONGOING WORK

1. Further work on the dragging brake aspect is needed, as indicated in A-4 above, to validate, without doubt, the provisions of the draft National Code for Flameproof Underground Diesel Machines.

2. This attempt to interest universities in coal producing areas in coal mine safety has failed because the supervising professor has left UBC to work in Ontario.

TITLE: MINE SAFETY STANDARDS

CONTRACTOR:	Canadian Standards Association	FILE NUMBER:	0-9033	FUNDING	
		BEGIN/END:	Sept. 80/Oct. 81		
				CANMET:	$ 9,000
CANMET SCIENTIFIC		ACTIVITY:	Energy Technology	CONTRACTOR:	5,625
		SUB-ACTIVITY:	Coal	OTHER:	20,000
AUTHORITY:	J.A. Bossert	TECHNOLOGY:	Mining	TOTAL:	$34,625

OBJECTIVES

To establish national consensus standards for mine safety, particularly in fields where CANMET is involved in certifying equipment and materials for use in underground mines.

PROCEDURE

To establish a steering committee and several technical committees covering various aspects of electrical and mechanical mine safety. The technical committees will prepare consensus standards with the assistance of a CSA standards administrator and the resulting standards will be published under the "M" series of CSA standards.

RESULTS

The new steering committee was able to set up three new technical committees and to obtain funding and technical support from a number of provincial governments, manufacturers of mining products and mining companies. One steering committee meeting and six technical committee meetings have been held and preliminary drafts for four new standards have been prepared.

New drafts of standards were prepared for:

1. Use of electricity in mines.
2. Underground diesels.
3. Fire-resistant conveyor belting.
4. Fire-resistant hydraulic fluids.

APPLICATION AND ONGOING WORK

It is expected that several more meetings will be required to finalize the work already started. In addition, it is anticipated that there will be future requirements for standards on other subjects of interest to CANMET.

TITLE: QUANTITATIVE ANALYSIS OF DIESEL GENERATED ACIDIC AEROSOLS IN UNDERGROUND MINES

CONTRACTOR:	Laurentian University	FILE NUMBER:	0-9165	FUNDING	
		BEGIN/END:	Feb. 81/Apr. 82		
				CANMET:	$18,050
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D. Dainty	TECHNOLOGY:	Mining	TOTAL:	$18,050

OBJECTIVES

To assess the sulphuric acid and total acid levels associated with filterable particulates in dieselized underground mines.

PROCEDURE

Two sites in the dieselized Falconbridge Nickel Company's Strathcona Mine were chosen where Wagner ST2 Scooptrams (LHDs) were operating. The machines were powered by Deutz diesel engines fitted with Englehard PTX catalytic purifiers. The environment was sampled in two different ways; on filters and in midget impingers.

The samples were collected by drawing mine air at approximately 2 L/min through the filter and/or midget impinger with a personal sampler pump. Each of these samples was analyzed for pH, nitrate ion and sulphate ion. Some of the samples were analyzed for sulphate ion using two different methods, i.e., a lead specific ion electrode and spectrophotometric analysis.

RESULTS

1. It was determined that the Whatman GF/A glass fibre filters are best suited to the collection of underground respirable, combustible dust samples (RCD) for several reasons outlined in the text of the report.

2. The lead specific electrode method of determining the sulphate ion concentration was compared with a spectrophotometric procedure. The latter is superior and is recommended; it is faster, easier and gives comparable results.

3. The concentrations of sulphate ion in the stopes, ventilated by 566 m^3/min, where the ST2 LHD was 'mucking' were 0.31 mg/m^3 when the sample was collected 15.2 m from the muck pile, and 0.18 mg/m^3 at 24.4 m from the muck pile. The TLV for H_2SO_4 is 1.0 mg/m^3.

4. However, there is strong evidence that a substantial proportion of the sulphate concentration is not derived from H_2SO_4 but, possibly, from residual ammonia gas in the muck pile derived from blasting.

5. The nitrate ion concentrations appear to be very low; i.e., about 0.1 mg/m^3 in respirable diesel soot samples, suggesting that nitrates, considered as representative of NO_2 and HNO_3, are not a health problem.

6. These results suggest (but not definitively) that airborne acid in dieselized underground environments is not a problem from a health point of view. However, it is important to establish the source of the sulphate derived from sources other than sulphuric acid.

APPLICATION AND ONGOING WORK

Catalytic purifiers convert SO_2 to H_2SO_4 thus having a potentially negative impact on health. To determine whether they should continue to be used, it is necessary to definitively establish the H_2SO_4 levels in workings where they are applied. Therefore this work should be continued with emphasis on:

1. Determining other contributors to sulphate concentration.

2. Variation in acid concentration from exhaust pipe to the mine ventilation exit.

3. Using larger machinery in stopes having ventilation closer to the specified minimum.

TITLE: WEAR RATE AND EROSION OF A FUEL PUMP HANDLING 15% WATER/OIL FUEL EMULSION

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	9-9042	FUNDING	
		BEGIN/END:	Nov. 79/March 82		
CANMET SCIENTIFIC AUTHORITY:	D. Dainty	ACTIVITY:	Energy Technology	CANMET:	$19,622
		SUB-ACTIVITY:	Coal	CONTRACTOR:	--
		TECHNOLOGY:	Mining	OTHER:	--
				TOTAL:	$19,622

OBJECTIVES

To determine the wear rate and erosion of a fuel pump handling 15% water-in-oil fuel emulsion.

PROCEDURE

A testing rig incorporating a Bosch PE6AM75D fuel pump and six Bosch US-31902 injection nozzles (such as those employed on a Deutz F6L-714 engine), plus an emulsifying system incorporating an ORF hydroshear device, was constructed. A 15% water-in-oil fuel emulsion was pumped through the system for 3500 h at pump speeds and fuel delivery rates simulating a simplified LHD machine cycle. The equipment was then examined in detail to determine the effects of this operation.

RESULTS

1. The ball bearing at the governor end of the crankshaft failed due to high loading; not because of the nature of the circulated emulsion. The bearing failure was not considered abnormal for the loading and length of operation.

2. The delivery valve springs failed because of corrosion. The pump cross-section diagram indicates that these are replaceable.

3. Aside from the bearing and the DV springs, the pump parts are still considered to be in working condition although a degree of corrosion was evident on a number of them.

4. Although the present test showed good results, caution was expressed by the Bosch Company with respect to: (1) engine idle time, (2) emulsion temperatures, and (3) the composition of the water when considering operation of such a system in a mining environment and under actual operating conditions.

5. The pistons and barrels survived undue wear and corrosion even though an additional oil passage, under engine lube oil pressure and designed for multi-component fuel use, was not employed.

APPLICATION AND ONGOING WORK

The results of this contract are sufficiently positive to encourage CANMET to fund Deutz Canada to produce an on-board water-in-oil emulsion system for dynamometer and underground testing.

TITLE: DESIGN OF PROTOTYPE WATER/OIL FUEL EMULSIFICATION SYSTEM FOR UNDERGROUND DIESEL VEHICLES - PHASE 1

CONTRACTOR:	Deutz Diesel (Canada) Ltd.	FILE NUMBER:	9-9111	FUNDING	
		BEGIN/END:	Feb. 80/March 80	CANMET:	$4,125
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mining	TOTAL:	$4,125

OBJECTIVES

To make an engineering design feasibility study of a prototype water/oil fuel emulsification system, incorporating a Bosch-type fuel injection pump and injection system installed on a Deutz F8L-413FW indirect injection diesel engine to be mounted in a Jarvis Clark 500 load-haul-dump (LHD) machine.

PROCEDURE

The results of three prior contracts with the Ontario Research Foundation were examined by the contractor, particularly the research apparatus used to produce the water/oil emulsions in the successful study using the Deutz F6L-714 diesel engine.

RESULTS

The contractor produced a system design similar to the research apparatus and searched for and found commercial equipment which would properly function in the hostile mine environment. One major design change was the re-routing of the return water/oil mixture, bypassing the injection pump, to the water tank. The metering elements required to maintain a constant 15% water in the fuel require modification before incorporation into the prototype system. These modifications plus an alternative backup system have been described by the Scientific Authority for consideration by the contractor during Phase 2 of the contract.

APPLICATION AND ONGOING WORK

This contract represents satisfactory completion of Phase 1 - design of the water/oil emulsion system. Phase 2 will see the construction of the system, hopefully by the same contractor, for installation on a Jarvis Clark 500 LHD for ultimate proof-testing underground.

TITLE: ECONOMIC AND FEASIBILITY STUDY OF PUNCH MINING OF A COAL MINE HIGHWALL

CONTRACTOR:	Norwest Resource Consultants	FILE NUMBER:	9-9041	FUNDING	
		BEGIN/END:	Sept. 79/Apr. 80		
				CANMET:	$22,830
CANMET SCIENTIFIC		ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	B. Das	TECHNOLOGY:	Mining	TOTAL:	$22,830

OBJECTIVES

To provide analysis and evidence to assess whether the concept of punch mining of a coal mine highwall is practical and could be incorporated into long range strategic planning by coal operators in Canada. The study should further predict the economic feasibility of this type of operation.

PROCEDURE

1. Significant data on such operation were collected by the contractor.
2. Visit to specific site by the contractor, a representative of Calgary Power and the Scientific Authority.
3. Different punch mining and related operations were visited by the contractor and one operation by the Scientific Authority.
4. Discussions were held on several occasions between the Scientific Authority and the contractor.
5. Evaluations were made by Scientific Authority.

RESULTS

1. Contractor's report: "A Report on Punch Mining of a Coal Mine Highwall" has been prepared and submitted.
2. Seminar presentation with the participation of about 45 persons from coal operators, coal developers, coal-fired power plants, research laboratories, universities, mines inspectorate and other provincial coal mining regulatory bodies.

APPLICATION AND ONGOING WORK

1. Work may continue for demonstration project.
2. Negotiation is in progress with one operator for cooperation on punch mining.

TITLE: FOURIER TRANSFORM INFRARED SPECTROSCOPY & PHOTOACOUSTIC SPECTROSCOPY IN DETERMINATION OF BULK AND SURFACE OXIDATION OF COALS

CONTRACTOR:	St. Francis Xavier University	FILE NUMBER:	9-9047-2	FUNDING	
		BEGIN/END:	Oct. 80/Feb. 81		
				CANMET:	$23,876
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	H. Hamza	TECHNOLOGY:	Preparation	TOTAL:	$23,876

OBJECTIVES

1. To investigate the applicability of Fourier Transform Infrared Absorption Spectroscopy (FTIR) and Photoacoustic Spectroscopy (PAS) to the study of oxidized coals.

2. To investigate the nature of the oxidative process by identifying oxygen-containing functional groups generated by oxidation.

3. To investigate the feasibility of quantifying the degree of oxidation and, if possible, distinguish between the bulk and surface state of oxidation.

PROCEDURE

1. Obtain infrared absorption spectra of both fresh and artificially oxidized coal samples, using both FTIR and PAS methods. The former method requires fine grinding of the coal and mounting in a KBr pellet. Photoacoustic methods require little sample preparation.

2. Obtain "difference" spectra, using computer aided spectral subtraction techniques available with the FTIR spectrometer.

3. Attempt to quantify the degree of oxidation by comparison of spectra (oxidized vs fresh).

4. Identify functional groups and changes therein by characteristic absorption bands. Some chemical tests required to confirm spectral indications.

RESULTS

Results indicate that FTIR instrumentation provides a rapid and convenient indicator of the progress of aerial oxidation of bituminous coals. Carbonyl content has been shown to increase with degree of oxidation, with a corresponding decrease in methylene group content. These differences are readily seen through changes in the diagnostic infrared absorption at 1700 and 2900 cm^{-1}.

Chemical derivatization and modification, followed by further FTIR examination, indicate that the carbonyl groups generated by oxidation are of the aryl alkyl ketone type.

A model for oxidation is proposed.

The quality of spectra obtainable by using the novel photoacoustic detector was comparable to that obtained using conventional KBr pellets. Sample preparation problems are reduced considerably using the PAS system in conjunction with FTIR.

APPLICATION AND ONGOING WORK

It would be most useful for producer and end-user alike if the degree of oxidation of a coal could be easily and reliably determined. This feasibility study has shown that FTIR-PAS has considerable promise in this regard. Further work is required in several areas to confirm and expand upon the utility of the methods. Moreover, the degree of oxidation needs to be correlated with changes in the technological properties of the coal, i.e., floatability, dewatering behaviour, coke strength, etc.

TITLE: FURTHER FEASIBILITY STUDY ON THE USE OF FTIR TO QUANTIFY THE DEGREE OF OXIDATION OF COAL

CONTRACTOR:	St. Francis Xavier University	FILE NUMBER:	1-9091	FUNDING	
		BEGIN/END:		CANMET:	$30,000
CANMET SCIENTIFIC		ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. K. Michaelian	TECHNOLOGY:	Preparation	TOTAL:	$30,000

OBJECTIVES

1. Development of chemical treatment procedures to prepare coal samples for spectroscopic study.

2. Assessment of the applicability of Fourier Transform Infrared Absorption Spectroscopy (FTIR) and Photoacoustic Spectroscopy (PAS-FTIR) to quantify the degree of oxidation of coal.

PROCEDURE

1. a) Quantitative demineralization.
   b) Phase - transfer methylation.
   c) Alkaline hydrolysis.

2. a) FTIR spectra of coal in KCl pellets.
   b) PAS-FTIR spectra of coal as received.

RESULTS

1. a) Demineralization causes an increase in 1700 cm^{-1} absorption and a decrease in 1600 cm^{-1} absorption.
   b) Methylation causes a shift to higher frequency and an intensification of the carbonyl absorption band.
   c) Alkaline hydrolysis converts carboxylic acid groups to carboxylate ions.

2. a) Spectra of KCl pellets illustrate the effects of methylation and acid washing.
   b) PAS-FTIR spectra show increased resolution and sensitivity as compared with FTIR spectra of pellets.

APPLICATION AND ONGOING WORK

The Coal Research Laboratories (Edmonton) are planning another contract with St. Francis Xavier University. This new contract will emphasize chemical derivatization of coal.

TITLE: PYRITE REMOVAL FROM STEAM COALS USING A COUNTER-CURRENT FLUIDIZED CASCADE

CONTRACTOR:	University of Western Ontario	FILE NUMBER:	8-9047	FUNDING	
		BEGIN/END:	Aug. 78/Aug. 79		
				CANMET:	$15,339
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G.I. Mathieu	TECHNOLOGY:	Preparation	TOTAL:	$15,339

OBJECTIVES

To demonstrate the capability of the Counter-Current Fluidized Cascade (CFC) separator to remove pyrite from coal. This apparatus was recently developed as a dry beneficiation device at University of Western Ontario.

PROCEDURE

Its applicability was first tested using synthetic mixtures of coal and pyrite of various finenesses to evaluate the working parameters of the CFC. Upon satisfactory completion of this phase, a second series of coal-pyrite separation tests was attempted on a commercial coal under various operating conditions. The results were analysed by regression.

RESULTS

Despite a few shortcomings in the apparatus, the results of the experiments with the coal-pyrite synthetic mixtures were good.

Using the commercial coal, the pyrite was insufficiently liberated to permit a separation of more than 30%. Nevertheless, the CFC separator appears to be a potential technique to upgrade coal since it succeeded in removing nearly 50% of the ash minerals with the pyrite, despite the former being much lighter (but likely more liberated).

TITLE: BENCH-SCALE TESTING PROGRAM ON COAL CLEANING BY CHEMICAL COMMINUTION

CONTRACTOR:	Catalytic Enterprises Ltd.	FILE NUMBER:	9-9045	FUNDING	
		BEGIN/END:	Sept. 79/Aug. 80	CANMET:	$20,000
CANMET SCIENTIFIC AUTHORITY:	G.I. Mathieu	ACTIVITY:	Energy Technology	CONTRACTOR:	5,000
		SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Preparation	TOTAL:	$25,000

OBJECTIVES

1. To determine the effectiveness of the chemical comminution process developed by the Syracuse Research Cooperation (SRC) for sulphur and ash removal from two or more commercially significant Canadian coals.

2. To measure the ammonia consumption in chemical comminution.

3. Information obtained from Objectives 1 and 2 is to be combined in an analysis of the economic feasibility of chemical comminution for the treatment of three selected Canadian coals - DEVCO Lingan and Prince coals, and Luscar (Vancouver Island) coal. These were chosen because of their high sulphur content. However, the latter sample was received too late for study, thus its testing was cancelled by our authorization.

PROCEDURE

To compare:

1. Particle size distribution for chemical comminution with that of mechanical grinding.

2. Yields obtained, through dense liquid separation of the sized fractions, from each comminution procedure.

3. Sulphur values in the recoverable portion of the coal for both size reduction methods.

4. Ash levels in the recoverable portion of the coal for both techniques.

The experimental work was to employ the comminution conditions found optimal by SRC and to undertake the separation of the sulphur and ash from coal fractions, again, by means found best by SRC.

RESULTS

Test work at the University of Waterloo showed that both the Lingan and the Prince coals could be comminuted using gaseous ammonia under pressure but not when using ammonia solution. This method, when compared to conventional grinding, had the advantage of producing less fines, i.e., minus 149 µm material. Depending on the coal, this size fraction may vary from 1.7 to 4.3% by weight with chemical comminution, while it attained 8.6 to 9.0% by mechanical crushing (hammermill) for a similar overall size reduction. However, the ammonia comminution failed to liberate more sulphide and ash-bearing minerals than conventional milling. This is evidenced by the similar ash and sulphur analyses and coal yields obtained in the heavy liquid sink and float products of the sized fractions from the two types of comminution (Tables 4, 5 & 6). Although this contradicts the theory that chemical comminution should liberate more inorganic minerals than mechanical crushing at the same fragmentation, with the former breaking material along the mineralization planes (grain boundaries) while the latter does it at random (through grains), the greater effectiveness of ammonia comminution was not proven under the conditions tested using both Lingan and Prince coals.

The ammonia retention in coals was calculated at 50 kg/t for Lingan and 20 kg/t for Prince (for a 15-min pumping). In addition to being extremely costly, this ammonia would cause pollution hazards in both shipment and combustion of the coal. An acceptable level of NH_3 in the coals (1-2 kg/t) was obtained only after overnight pumping which is also costly. Therefore, ammonia recovery is a serious problem that must be solved before a commercially feasible process can be attained.

Although the report concludes that a better overall economy exists for chemical comminution over mechanical grinding in coal preparation plants with either equal feed (1200 t/h) or equal product yield (800 t/h), this conclusion is not based on present study premises, but uses Roberts & Schaefer figures of coal yields over 149 µm of 73 and 95% for mechanical crushing and chemical comminution, respectively (see p. 71). These do not agree with the Lingan and Prince test results of Table 7, pg. 57, which are summarized below.

Coal	Comminution	% Yield (+149 µm)
Lingan	Chemical	87.7
	Mechanical	82.4
Prince	Chemical	79.3
	Mechanical	72.4

This invalidates the economic analysis.

Briefly, both the lengthy chemical treatment period and ammonia retention preclude the commercialization of the process at present. However, a short ammonia attack which would swell and fissure the coal followed by probable easier mechanical grinding might be of economic interest, provided an inexpensive method of stripping NH_3 is found. Further research should be oriented towards these objectives.

TITLE: COLUMN FLOTATION SEPARATION OF HIGH SULPHUR COAL IN A TWO-INCH PILOT PLANT

CONTRACTOR:	Column Flotation Co. of Canada	FILE NUMBER:	1-9103	FUNDING	
		BEGIN/END:	Jan. 82/March 82		
				CANMET:	$29,918
CANMET SCIENTIFIC		ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	K.S. Moon	TECHNOLOGY:	Preparation	TOTAL:	$29,918

OBJECTIVES

To demonstrate the potential of the column flotation machine to separate pyritic sulphur and ash from a fine (minus 841 µm) eastern high sulphur coal and to determine the parameters required to operate an in-plant 1.83 m (6 ft) column flotation machine.

PROCEDURE

A series of column flotation tests on high sulphur coal from DEVCO, utilizing a 5.08 cm (2 in.) column flotation machine, is required to study the following objectives.

1. Testing the column flotation performance for:
   a) Pulp density and throughput.
   b) Recovery and ash and sulphur contents in clean coal product.
   c) Effect of particle size on separation efficiency.
   d) Effect of dosage level of collectors and frothers.
   e) Effect of the pH of the pulp during flotation.
2. Demonstration of the column flotation for fine (minus 841 µm) coal cleaning.
3. Identification of possible problems and recommendations for the scale-up to a 1.83 m (6 ft) column.

RESULTS

1. Contract report by Column Flotation Co. of Canada "Column Flotation Separation of High Sulphur Coal in a Two-Inch Pilot Plant", March 26, 1982.
2. Investigation Report by K.S. Moon and L.L. Sirois, ERP/MSL 82-67(IR), "Beneficiation of High Sulphur Coal by Column Flotation", June 1982 (in preparation). This report evaluates the data obtained in this contract, for the various factors outlined under "Procedure".
3. This contract only called for the collection of data, not for a detailed evaluation of the data.

APPLICATION AND ONGOING WORK

The pilot plant investigation using a 5.08 cm (2 in.) counter current column flotation machine demonstrated firmly that it is capable of cleaning high sulphur coal. A plan for in-plant test work using an actual large column flotation machine is being prepared.

TITLE: THERMAL DEWATERING OF SASKATCHEWAN LIGNITES - PHASE 2

CONTRACTOR:	Saskatchewan Power Corp.	FILE NUMBER:	8-9125-5	FUNDING	
		BEGIN/END:	Sept. 79/March 80		
CANMET				CANMET:	$13,610
SCIENTIFIC		ACTIVITY:	Energy Technology	CONTRACTOR:	13,610
AUTHORITY:	J. Price	SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Preparation	TOTAL:	$27,220

OBJECTIVES

To determine:

1. If Saskatchewan lignites can be dewatered satisfactorily in a laboratory autoclave at high temperatures (up to 350°C) and high pressures.
2. Effects of dewatering under liquid water and different oils.
3. Effects of H_2 and Syngas atmospheres on thermal dewatering.
4. Effect of short residence times on thermal dewatering.
5. Amount of moisture absorbed by dewatered lignites.
6. Effect of limestone on sulphur removal during thermal dewatering.
7. Mass, energy, alkali, and sulphur balances for thermal dewatering.

PROCEDURE

Six lignites from Estevan, and one each from Coronach, and Shaunavon, Saskatchewan were thermally dewatered at several temperatures (up to 350°C), pressures, and residence times. A 30-g sample was reacted in 150 mL of water (or other liquid) in a Parr model 4563 Mini-reactor at the appropriate temperature and residence time. The lignite was then removed from the water, drained, cooled, and removed from the reactor, and the solids and liquids were weighed. Proximate, ultimate moisture, ash and calorific analyses were made on solids while liquids were analyzed for Na and K and gases were analyzed for CO_2, O_2, CO, H_2, H_2S and N_2. Mass and energy balances were done on the products.

RESULTS

Saskatchewan lignites can be dewatered by heating to 250-350°C at saturated vapour pressures of water. Dewatering experiments at temperatures from 150 to 300°C in Phase 1 (File No. 7-9128; previously published) showed maximum dewatering occurred at 300°C and average moisture for Estevan lignites was reduced from 34 to 9%; not all lignites dewatered as readily as the Estevan samples. In Phase 2, lignites that did not dewater well at low temperatures gave dry products at 350°C. Lignites dewatered better when heated in an atmosphere of steam than when immersed in water, but alkali removal was poorer. Lignites dewatered better under light cycle oil (2-3% moisture in product after 300-350°C treatment) than under slurry oil or water, but samples absorbed from 5 to 9% oil. Lignites in H_2 or H_2/CO atmospheres generally dewatered readily (and hydrogenated slightly) but generally readsorbed water readily. Equilibrium moistures of lignites before and after thermal dewatering were generally the same until reaction temperatures exceeded 200-250°C. Addition of limestone facilitated sulphur removal during reaction. The sodium content for lignites with high amounts of Na can be reduced by ~33 to 50% upon dewatering. A crude estimate of the cost of thermal dewatering is about $10/t.

APPLICATION AND ONGOING WORK

To improve calorific value of lignite fuel and to reduce its transportation cost to Eastern generating stations.

Phase 3 - Establishment of Optimum Conditions for Dewatering.

Phase 4 - Conceptual Design and Economics of a Full-Scale Commercial Plant.

TITLE: THERMAL DEWATERING OF LIGNITE AND PEAT - PHASE 3

CONTRACTOR:	Saskatchewan Power Corp.	FILE NUMBER:	9-9164	FUNDING	
		BEGIN/END:	Apr. 80/March 81		
				CANMET:	$35,318
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	35,318
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J. Price	TECHNOLOGY:	Preparation	TOTAL:	$70,636

OBJECTIVES

Lignites and peats were thermally dewatered in newly designed reaction vessels to determine the effects of higher temperatures, particle size and shorter residence times on the equilibrium moisture content and other chemical and physical properties of the dried products. Lignites were also dewatered under heavy and light crude oils to determine if these materials could improve the dewatering process.

PROCEDURE

Four lignites were sampled from three mines in the Estevan area of Saskatchewan and from the Onakawana deposit in Ontario. Representative samples were dewatered in a Parr Model 4652 Reactor by immersing 30-60 g lignite or peat under 150 mL water and heating up to 400°C for the appropriate residence time. Proximate, ultimate, moisture, ash, calorific, alkali content, density, grindability, FSI and spontaneous combustion analyses were made on the solid products. Analyses of total inorganic carbon, total organic carbon, anions, biological oxygen demand, and oxygen reduction potential were made on selected aqueous products.

RESULTS

Thermal dewatering substantially reduces the moisture content of lignite from 30 to 45% to 15 to 25% by treatment at 300°C. Increasing the temperature yields a drier product, but involves substantially higher pressures, since the operating pressure equals the saturated vapour pressure of water. Very little thermal dewatering occurs below 250°C; above 350°C thermal decomposition becomes significant. Residence times longer than about 5 min do not yield a substantially drier product. Increasing particle size appears to decrease the product moisture content for Estevan lignites. The opposite trend was observed for Onakawana lignites. The maceral composition of the original sample (especially the amount of inertinite) affects dewatering. More significant is the extent of oxidation and mineralization of the sample. The equilibrium moisture level of lignite is reduced by thermal dewatering, and is generally below the actual moisture level. Very little readsorption of water should occur under normal atmospheric conditions, reducing the chance of spontaneous combustion. Mineral matter is leached from the lignite during the thermal dewatering process.

APPLICATION AND ONGOING WORK

To improve the calorific value and reduce the alkali content of lignite fuel, and to reduce transportation costs, making it a more attractive fuel for boilers in central Canada.

Continuing Work

Phase 4 - Conceptual Design and Cost Estimate of 150 t/h Preparation Plant.

Phase 5 - Design and Construction of a Continuous Process Development Unit.

TITLE: BENEFICIATION OF TEN METRIC TONS OF RAW METALLURGICAL COAL TO THREE SPECIFIED ASH LEVELS

CONTRACTOR:	Great West Steel Industry	FILE NUMBER:	8-9127	FUNDING	
		BEGIN/END:	July 79/March 80		
				CANMET:	$55,042
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J.F. Gransden	TECHNOLOGY:	Carbonization	TOTAL:	$55,042

OBJECTIVES

The coking coals of Western Canada are generally low in sulphur content and have fair to good coking properties. However, the ash content of the cleaned coals is sometimes high relative to premium coals from the U.S.A. Commercially, coal is cleaned to an ash level based upon market economics of credits for ash reduction and the yield of cleaned product. Limited studies by CANMET in the past on laboratory washed coal have shown that the caking and coking properties are markedly affected by relatively small changes in coal ash content. Therefore, it may be economically and technically attractive to clean certain coals to lower levels of ash than is currently practised to allow companies to compete for new and existing markets by offering an expanded range of coal quality.

PROCEDURE

Bulk samples of four Western Canadian coals were cleaned to three ash content levels: a "commercial" ash content level and ash levels above and below this value.

Washability curves of two size fractions were obtained for each of the four coals. A pilot plant that simulates commercial washing and includes heavy media, water cyclones and froth flotation was then used to obtain up to 3 tons of coal at each ash level. A plant balance with yields of the circuits and ash contents of the products were obtained.

RESULTS

The four coals were cleaned to the following ash contents and yields of clean coal.

	% Ash	% Yield
Coal A	8.5	87.3
	7.3	73.4
	5.8	69.7
Coal B	6.8	95.8
	5.1	88.6
	3.2	82.2
Coal C	9.3	67.7
	6.6	62.0
	5.0	54.9
Coal D	10.6	85.6
	8.4	69.4
	6.5	51.4

APPLICATION AND ONGOING WORK

The chemical, rheological and petrographic properties of the washed coal are being determined at CANMET. The coals are being coked in a 300-kg capacity technical-scale coking oven, both alone and in blends with other coals.

TITLE: DEGRADATION OF COKE IN THE BLAST FURNACE - PHASE 2

CONTRACTOR:	McMaster University	FILE NUMBER:	9-9050	FUNDING	
		BEGIN/END:	Jan. 80/Dec. 80		
				CANMET:	$29,552
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J. Gransden	TECHNOLOGY:	Carbonization	TOTAL:	$29,552

OBJECTIVES

Alkalies in the blast furnace cause coke degradation which means lower furnace productivity and higher fuel rates. The objective of this contract is to determine the mechanism by which alkalies decrease coke strength so that their effect can be minimized.

PROCEDURE

The tensile strengths of discs cut from a Canadian commercial blast furnace coke were measured before and after impregnation of potassium. Four impregnation samples were placed in a flowing mixture of argon and potassium vapour at 800, 900, 1000 and 1200°C, the potassium partial pressure being controlled at 10^{-4}, 10^{-3} or 10^{-2} Bar. The amounts of potassium in the samples were measured by chemical analysis. The weight loss and reduction in tensile strength of the discs were measured after oxidation in three compositions of gas mixtures consisting of argon-carbon dioxide-carbon monoxide at three different temperatures and various reaction times.

RESULTS

The oxidation of coke without potassium impregnation was very temperature sensitive. Weight loss at 800°C was undetectable after 1100 min but was <30% after 120 min of 1200°C. The reduction in tensile strength of the coke was related only to the weight loss and not to the reaction conditions, i.e., temperature and oxidizing gas composition.

Potassium reduced the tensile strength of the coke before oxidation, the strength becoming nil at a potassium content of 4.5%. Potassium also greatly increased the rate of oxidation. For example, coke containing about 2% potassium suffers a weight loss of 60% at 800°C after 1100 min.

It is concluded that potassium reduces coke strength by

1. formation of intercalation compounds;
2. increasing weight loss by oxidation, especially at lower temperatures.

The latter shrinks the size of the domain for indirect reduction of iron ore in the blast furnace, thus increasing the thermal requirement and therefore the fuel rate.

APPLICATION AND ONGOING WORK

Reactivity of the different forms of carbons in coke will be measured and a reactivity test of relevance to the blast furnace designed.

TITLE: DEGRADATION OF COKE IN THE BLAST FURNACE - PHASE 3

CONTRACTOR:	McMaster University	FILE NUMBER:	0-9115	FUNDING	
		BEGIN/END:	Jan. 81/Dec. 81		
				CANMET:	$33,046
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J.F. Gransden	TECHNOLOGY:	Carbonization	TOTAL:	$33,046

OBJECTIVES

Alkalies in the blast furnace cause coke degradation which means lower furnace productivity and higher fuel rates. The objective of this contract is to determine the mechanism by which alkalies decrease coke strength so that their effect can be minimized.

PROCEDURE

Tensile strengths of commercial coke samples were measured, before and after vapour phase impregnation of potassium and after reaction in atmospheres oxidizing to carbon for various times and temperatures. The different optically anisotropic textures in coke samples were determined microscopically. This was repeated after oxidation of the coke samples and also after potassium impregnation and oxidation. A commercial coke and laboratory coke made from a low-volatile coal and a high-volatile coal were used.

RESULTS

Coke absorbs potassium vapours from the gaseous phase in the blast furnace to form intercalation compounds that weaken its strength. Oxidation weakens its strength further. A catalytic effect of alkalies promotes this oxidation at lower temperatures and increases its rate.

The different optically anisotropic textures in the cokes were found to oxidize at different rates. For example, "creased flow" and "medium mosaic" were more inert than "isotropic". An index called the "Relative Micro Reactivity" was defined which ranks the textures according to their reactivity. When potassium is present in the samples, the difference in reactivity between the textures is less. Concluding, control of the form of texture in the coke would allow marked improvements in coke performance in the blast furnace.

APPLICATION AND ONGOING WORK

Further commercial and other cokes will be examined to test the generality of the results.

TITLE: FLUID BED GASIFICATION OF FINE COAL WASTE

CONTRACTOR:	British Columbia Research Council	FILE NUMBER:	7-9033-5	FUNDING	
		BEGIN/END:	March 78	CANMET:	$42,073
CANMET SCIENTIFIC AUTHORITY:	M. Avedesian	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Gasification	TOTAL:	$42,073

OBJECTIVES

To determine the technical feasibility of gasifying fine coal waste in the B.C. Research fluidized bed gasifier and to determine the optimum operating conditions.

PROCEDURE

The B.C. Research fluidized bed reactor was used to gasify fine coal waste. The study was conducted under the following headings:

1. Modifications to the existing equipment.
2. Material preparation.
3. Shake down of equipment.
4. Optimization.
5. Evaluation of results.
6. Techno-economic assessment.
7. Preparation of final report.

RESULTS

Results of the study indicate that gasification of fine coal waste is technically feasible. However, the economic feasibility of gasification of coal waste appears to be marginal on the basis of reactor preformance in this study and current prices of natural gas in Western Canada.

TITLE: PRODUCT CONTROL IN FLUID BED GASIFICATION AND LOW BTU GAS TURBINE COMBUSTOR - PHASE 2

CONTRACTOR: Carleton University	FILE NUMBER:	8-9112	FUNDING	
	BEGIN/END:	March 79/March 80	CANMET:	$45,072
			CONTRACTOR:	--
CANMET	ACTIVITY:	Energy Technology	OTHER:	--
SCIENTIFIC	SUB-ACTIVITY:	Coal	TOTAL:	$45,072
AUTHORITY: L.P. Mysak	TECHNOLOGY:	Gasification		

OBJECTIVES

1. To conduct fluidized bed gasification experiments with three Canadian coal types to establish the effects of coal type and operating conditions on the gas yield, composition and conversion efficiency.

2. To vary gasification conditions as necessary to produce a constant gas with constant combustion gas characteristics for the coals used. A control philosophy would be developed to allow selection of these operating conditions.

3. To model the gasifier theoretically to establish relationships between control variables and the product composition.

4. To operate the gasifier in series with the combustor which would be used to establish the effective interlocking control system between the gasifier and combustor.

PROCEDURE

Use bench-scale facility developed during 1978-79 (to gasify coal, clean the gases of ash and burn the gaseous products in a gas-turbine type combustor) and make improvements to it as seemed advisable or necessary.

The three coals used as feed were Nova Scotia high-volatile bituminous, Estevan lignite and Coronach lignite from Saskatchewan.

RESULTS

Not all of the objectives were met. Time was consumed on modifications to the system which included: a water cooled traversing probe for gas and solids sampling and temperature measurements; a coal feeder capable of being pressurized; re-design of the igniter system; instrumentation added to aid in diagnostics of the fluid bed; changes made to the steam supply; a new combustor designed and built to allow detailed probing of the combustion region; and several additional diagnostic tools intended specifically for the combustor.

Numerous preliminary runs were conducted to become familiar with the operation of the system. In spite of many preliminary trials, no successful gasification runs were sustained long enough to be certain that steady-state had been achieved with the bituminous coal. The coking nature of the coals resulted in agglomeration of at least part of the bed causing a loss in fluidization.

APPLICATION AND ONGOING WORK

Develop Canadian expertise in the area of coal conversion. This work is being continued for another year.

TITLE: DEVELOPMENT OF FLUID BED GASIFICATION CONTROL PARAMETERS FOR A RANGE OF CANADIAN COALS - PHASE 3

CONTRACTOR:	ASECOR Ltd.	FILE NUMBER:	9-9149	FUNDING	
		BEGIN/END:	Apr. 80/March 81		
				CANMET:	$59,764
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	L. Mysak	TECHNOLOGY:	Gasification	TOTAL:	$59,764

OBJECTIVES

1. To obtain gasification data for two lignite coals, study the combined gasifier-combustor behaviour with these two coals and correlate the results.

2. To develop appropriate theoretical understanding of fluidized bed gasification processes to predict optimum operating conditions as well as to aid in the control of the gasifier to obtain these optimum conditions.

3. To develop a mini-computer based control system to allow optimum control over the gasifier to be exercised.

PROCEDURE

The existing bench-scale fluid bed gasifier was used. Coal feed rate ranged from 0.11 to 0.33 kg/h. Fluidization was achieved in the bed using oxygen or air.

The methodology for the development of the control system was: to formulate the detailed procedure, build, test and debug the mini-computer based control system, control effectiveness verification by operating the gasifier with manual and computer control, and comparison of the results with the predictions of models.

RESULTS

Some gasification data were obtained. The results are still incomplete due to limitations in the gasifier. Some of the limitations have been improved upon and later work should clarify some of the discrepancies in the results obtained.

The theoretical model developed during this period is described, with results of optimization and the effect of operating away from the optimum condition shown in detail for a well-stirred reactor. The model for a plug flow reactor is described, but detailed results will be presented in a later report.

The mini-computer based control system has been developed. The hardware and software being used in this system are described. Final installation and testing of the system has not been completed.

APPLICATION AND ONGOING WORK

To assist in the development of coal conversion expertise in Canada. The unfinished portion of this work is being done in 1981/82.

TITLE: SPOUTED BED GASIFICATION OF WESTERN CANADIAN COKING COALS

				FUNDING	
CONTRACTOR:	University of British Columbia	FILE NUMBER:	7-9073-2		
		BEGIN/END:	Apr. 78/May 79	CANMET:	$103,928
		ACTIVITY:	Energy Technology	CONTRACTOR:	--
CANMET SCIENTIFIC AUTHORITY:	G.V. Sirianni	SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Gasification	TOTAL:	$103,928

OBJECTIVES

1. To design and construct a 305-mm I.D. spouted bed coal gasifier at the Chemical Engineering Department of the University of British Columbia.
2. To commission, debug, and demonstrate the operation of the gasifier.

PROCEDURE

1. Detailed design of the spouted bed coal gasifier, coal feeding system, cyclones and off-gas cooler-washer.
2. Specifications and procurement of off-gas incinerator, propane burner and safety controls.
3. Construction of equipment and supporting structure.
4. Assembly of equipment.
5. Initial testing of equipment, i.e., the spouted bed, propane burner, coal feeding system, off-gas cooler-washer and incinerator.
6. Commissioning runs, including initial cold runs followed by hot runs to test operation of the assembled plant. Formulating start-up and shut-down procedures.
7. Six preliminary gasification runs of 12 h duration to demonstrate operation of the plant.
8. Preparation of final report to be received by EMR. The report will include further work planned for the next year.
9. Presentation of a technical paper at a 1-day coal conversion seminar in Ottawa.

RESULTS

The 305-mm I.D. spouted bed coal gasifier was successfully built, debugged and commissioned by May 79.

APPLICATION AND ONGOING WORK

An experimental program to determine if moderately and highly caking coals can be gasified in the 305-mm I.D. spouted bed gasifier is being carried out in FY 79/80.

TITLE: SPOUTED BED GASIFICATION OF WESTERN CANADIAN COALS - CONTINUATION

CONTRACTOR:	University of British Columbia	FILE NUMBER:	0-9143	FUNDING	
		BEGIN/END:	Apr. 81/March 82		
				CANMET:	$98,937
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G.V. Sirianni	TECHNOLOGY:	Gasification	TOTAL:	$98,937

OBJECTIVES

1. Extend range of coals gasified to provide broader data bank on behaviour of Western Canadian coals.
2. Compare spouted and fluid bed gasification.
3. Obtain in-bed gas composition and temperature profiles for use in mathematical model.
4. Extend mathematical model to predict gas composition as a function of operating and design variables.
5. Provide further data for gasifier scale-up.

PROCEDURE

1. Design and test in-bed sampling rig.
2. Revamp off-gas burner; design gas distributor.
3. Install distributor and gasify Forrestburg and Sukunka coals.
4. Spouted bed gasification of Crows Nest, Byron Creek and Roseyln coal and Saskatchewan lignite.
5. In-bed gas composition measurements.
6. Improve mathematical model.
7. Provide data as needed for scale-up.
8. Final report.

RESULTS

Typical results for three different types of coal show agreement between experimental and calculated values of gas composition are fairly good.

Both spouted beds and fluidized beds can successfully gasify caking and non-caking coals. The slight edge of one over the other depends on the type of coal. In general, the fluid bed was found to give better control of the gasifier operating conditions.

APPLICATION AND ONGOING WORK

This project is continuing in FY 82/83 under file number 2-9000.

TITLE: SPOUTED BED GASIFICATION OF WESTERN CANADIAN CAKING COALS

				FUNDING	
CONTRACTOR:	University of British Columbia	FILE NUMBER:	9-9152	CANMET:	$76,941
		BEGIN/END:	Apr. 80/March 81	CONTRACTOR:	--
CANMET SCIENTIFIC AUTHORITY:	G. Sirianni	ACTIVITY:	Energy Technology	OTHER:	--
		SUB-ACTIVITY:	Coal	TOTAL:	$76,941
		TECHNOLOGY:	Gasification		

OBJECTIVES

1. Determine the effects of the recycle of carryover product on gas quality, steady state carryover composition and operational stability.
2. Evaluate the operation with a char bed as opposed to a gravel bed.
3. Determine maximum moisture content of coal for gasification.
4. Assess composition of minor constituents in gas-sulphur, tar and dust.
5. Assess mathematical models for scale-up.

PROCEDURE

1. Recycle cyclone-catch solids to gasifier through a separate feeder.
2. Install internal cyclone in freeboard of gasifier to test internal recycle of bed carryover.
3. Set up analytical equipment to carry out Objective 1.
4. Prepare char bed to replace gravel bed.
5. Gasifier trials with char bed using Forrestburg, Coleman and Sukunka coals.
6. Study the effects of coal moisture.
7. Extended trials.
8. Assess and improve mathematical model.
9. Prepare final report.

RESULTS

In the producer gas, typical values of H_2S were 115-160 ppm, SO_2 20-80 ppm; only trace amounts of COS were detected. Particulates in the gas were less than 0.8 g/m^3. Recycle of char was accomplished successfully. Carryover of char was higher when a char bed was used instead of a gravel bed. Coal with high surface moisture was more difficult to feed than coal without. Extended runs went smoothly. The use of an air/coal ratio up to 3.5, based on dry coal, gave good quality gas with a heating value of 4.0 MJ/m^3. The steam coal ratio influences the H_2/CO ratio of the gas. However, the heating value is not changed because the heating value of H_2 and CO are almost identical.

APPLICATION AND ONGOING WORK

This work is being continued in FY 81/82 under file number 0-9143. Also, another contract will be awarded to determine the feasibility of scaling-up the spouted bed gasifier from about 45 kg/h to about 450 kg/h.

TITLE: SPOUTED BED GASIFICATION OF WESTERN CANADIAN COALS - CONTINUATION

				FUNDING	
CONTRACTOR:	University of British Columbia	FILE NUMBER:	8-9111		
		BEGIN/END:	May 79/March 80		
				CANMET:	$66,605
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G.V. Sirianni	TECHNOLOGY:	Gasification	TOTAL:	$66,605

OBJECTIVES

1. To evaluate top feed versus bottom feed to a spouted bed gasifier.
2. To evaluate steam injection into spout versus steam injection into annulus.
3. To optimize operating conditions for caking and non-caking coals.
4. To carry out extended runs under optimum conditions.

PROCEDURE

1. Operate the gasifier with top feeding to compare with bottom fed tests.
2. Evaluate steam injection in spout versus annulus.
3. Design modifications for indirect air preheating.
4. Determine effect of coal feed size, i.e., Forrestburg and Sukunka coals.
5. Optimization test on Forrestburg coal.
6. Optimization test on Sukunka coal.
7. Optimization test on Coleman coal.
8. Carry out long proving runs under optimum conditions.
9. Prepare final report.

RESULTS

1. Bottom feeding generally gave a more uniform temperature pattern and was easier to control particularly when caking coals were gasified.
2. No significant effect of steam injection location could be determined.
3. Optimum air and steam flowrates were determined. At a given air and steam flowrate, the coal feed rate stood out as the most important parameter because it determined the bed temperature and height and ultimately governed the performance of the reactor.
4. Runs up to 9 h suggested that steady state conditions were reached after 1-2 h.

APPLICATION AND ONGOING WORK

The work is being continued in FY 80/81 to:

1. Determine effect of recycle of carryover product on gas quality, steady state carryover composition and operational stability.
2. Evaluate operation with char bed as opposed to inert gravel bed.
3. Determine maximum moisture content of coal for gasification.
4. Assess composition of minor constituents in gas-sulphur, tar and dust.
5. Assess mathematical model for scale-up.

TITLE: SHAUNAVON COAL UTILIZATION - PHASE 2

CONTRACTOR:	Saskatchewan Power Corporation	FILE NUMBER:	8-9059	FUNDING	
		BEGIN/END:	March 79/March 81		
				CANMET:	$244,400
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	244,400
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G. Siriani	TECHNOLOGY:	Gasification	TOTAL:	$488,800

OBJECTIVES

For a 150/300 MW power plant (required in the late 80's) study was undertaken to investigate conventional and advanced power generation with minimum water usage.

PROCEDURE

Phase 1: Techno-economic assessment of 15 advanced processes - March 78.

Phase 2: (a) Coal and water survey - March 79

(b) Detailed techno-economic assessment of:

(i) Lurgi-Steag combined cycle,

(ii) Lurgi-other combined cycle,

(iii) Shell-Koppers combined cycle,

(iv) possible Texaco combined cycle, in comparison with the base case (pulverized fuel with flue gas desulphurization) March 81.

Phase 3: Conceptual design of one process scheme - March 82;

Phase 4: Design of the 150/300 MW plant and mining operation, start construction 1983/84.

Phase 5: Electricity generation - 1989/90.

RESULTS

A coal gasification combined cycle plant will become suitable for use with the Shaunavon coal deposits when coal costs (including transportation) rise to $19.56/t ($ 1979). A mine mouth power station therefore favours a conventional pulverized coal-fired power plant. Hence the study is terminated.

APPLICATION AND ONGOING WORK

The relevance of these conclusions (results) to other sites in Saskatchewan may be considered by Saskatchewan Power. Also there is a possibility that Saskatchewan Power may decide to investigate technological uncertainties regarding the probability of a turbine inlet temperature of 1200°C. If so, this decision would not be made before the spring of 1982.

TITLE: FEASIBILITY OF A PROCESS WHICH INVOLVES A REACTION IN MOLTEN SALT TO SIMULTANEOUSLY DESULPHURIZE AND PRODUCE LOW BTU GAS FROM CANADIAN COALS

CONTRACTOR:	Surveyer, Nenniger & Chenevert Inc.	FILE NUMBER:	8-9114	FUNDING	
		BEGIN/END:	Sept. 79/Feb. 80	CANMET:	$31,724
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G.N. Banks	TECHNOLOGY:	Gasification	TOTAL:	$31,724

OBJECTIVES

1. Conduct a literature search to establish the present status of schemes which use a molten salt technique to simultaneously desulphurize and gasify coal. Include, in this search, gasification schemes which utilize a molten iron bath and lime-bearing slag for desulphurization and identify technological uncertainties.

2. Determine optimum composition of the baths.

3. Design a bench-scale facility to experimentally corroborate predictions of Objective 2.

4. Prepare a cost estimate of the system designed in Objective 3.

5. Develop an experimental program for a range of Canadian coals, using the facility designed in Objective 3.

PROCEDURE

1. Over 100 references were consulted to determine the present state-of-the-art and scale of operations which are employed to simultaneously gasify and desulphurize coal, using a molten salt bath. The basic features of the more viable processes were summarized and compared.

2. Preliminary equilibrium calculations were used to evaluate the performance of various alkaline and heavy metal carbonates in the retention of sulphur and then detailed thermodynamic calculations were used to determine the equilibrium composition of the product gas when selected carbonates were utilized. An interactive computerized thermodynamic system called F.A.C.T. was used for these calculations.

3. Design calculations were done on the basis of mass flowrates/volumetric capacity, temperature, pressure, corrosion resistance and safety.

4. Preliminary cost estimates were made for fixed equipment, based on the most appropriate flow diagrams developed.

5. An experimental program, based on a maximum coal feed rate of 2 kg/h, combined with appropriate mixtures of carbonates, air (oxygen) and steam was outlined.

RESULTS

1. The literature search indicated that processes developed by MW Kellog and Atomics International were the most promising areas for potentially profitable research.

2. Thermodynamic studies indicated that heavy metal carbonate additions to the salt bath would result in the production of relatively sulphur-free gases.

3. A bench-scale facility was designed and its total cost, excluding standard ancilliary laboratory equipment, was estimated at $36,400 (1980 $ Can.).

4. An experimental program to investigate the effect of process variables on a range of Canadian coals was outlined.

APPLICATION AND ONGOING WORK

It is anticipated that Surveyer, Nenniger and Chenevert Inc. will be submitting an unsolicited proposal to investigate the gasification of Canadian coals, using the molten salt technique outlined in this report.

TITLE: LIGNITE REACTIVITY - PHASE 2

CONTRACTOR:	Saskatchewan Power Corp.	FILE NUMBER:	8-9125-1	FUNDING	
		BEGIN/END:	Apr. 79/March 80		
				CANMET:	$31,600
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	31,600
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	L.P. Mysak	TECHNOLOGY:	Gasification	TOTAL:	$63,200

OBJECTIVES

To evaluate the reactivity of lignite coals in the province of Saskatchewan. These coals are evaluated as to their usefulness in gasification applications; primarily for the production of fuel gases, methane and hydrogen.

PROCEDURE

Coronach and Estevan coals were gasified with steam and compressed air in a fixed-bed batch mode reactor. The effect of pressure on the formation of gas was investigated. Gasification was carried out on 500 g of coal at pressures from 0.1 to 6 MPa and initial reactor temperatures of 440-690°C. Experiments were carried out at two air flowrates (4 and 8 L/min) with a constant steam flowrate of 2.2 g/min and at two steam flowrates (2.2 and 8.8 g/min) with a constant air flowrate of 4 L/min.

RESULTS

Twenty-three experiments were conducted. A significant increase in heating value was observed when the reactor pressure was increased from atmospheric to higher pressures at all the steam and air flowrates. The thermal efficiency of the reactor varied from 56-80%. Under identical experimental conditions, Estevan lignite seems to give marginally higher heating values than the Coronach lignite.

APPLICATION AND ONGOING WORK

This work will provide data on optimal process variables for the production of low BTU gas by gasification of Saskatchewan lignites for possible use in a combined cycle power generation system.

Phase 3 will include continuous operation of a research scale fixed-bed gasifier.

TITLE: TECHNICAL AND ECONOMIC BENEFITS OF MINEHEAD POWER GENERATION USING VARIOUS FORMS OF LIGNITE

CONTRACTOR:	Onakawana Development Ltd.	FILE NUMBER:	9-9167	FUNDING	
		BEGIN/END:	Apr. 80/Jan. 81		
				CANMET:	$24,319
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	24,319
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D. Fung	TECHNOLOGY:	Gasification	TOTAL:	$48,638

OBJECTIVES

1. Establish the feasibility of generating electric power by means of an integrated combined cycle installation.

2. Assess the economics and efficiency of converting the Onakawana lignite into medium calorific value gas in a commercially available gasifier.

PROCEDURE

The feasibility study was performed by Ebastec Lavalin Inc. of Toronto.

RESULTS

Three gasification processes - Winkler, Koppers-Totzek, and Texaco - were assessed for power supply at the minehead using Onakawana lignite. The Winkler process, combined with purchased power, is considered the most economical method of operation. Assuming a 13% interest rate and a depreciation life of 20 years with a discounted cash flow return of 16%, the lignite can be processed into a 10 MJ/m^3 gas at a transfer cost in 1981 dollars of $8.31/GT. The total capital cost in 1981 dollars would be $240 million, with an annual production cost of $60 million. The plant would produce 1368 GJ/h of gas product with a feed of 4125 t/d.

APPLICATION AND ONGOING WORK

Of the three processes, Winkler is the most economical for power supply at the minehead. An alternate route for methanol production from the lignite will be investigated in Phase 2 of the Onakawana study.

TITLE: PRODUCTION OF LIQUID FUEL FROM COAL

CONTRACTOR: Algas Resources Ltd.		FILE NUMBER:	8-9125-4	FUNDING	
		BEGIN/END:	Sept. 79/Oct. 80		
				CANMET:	$166,433
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	166,433
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	166,433
AUTHORITY: M. Ternan		TECHNOLOGY:	Liquefaction	CROWS NEST RESOURCES:	75,000
				TOTAL:	$574,299

OBJECTIVES

To perform an engineering cost study which would indicate the feasibility of producing hydrocarbon liquid fuel from Western Canadian coal. The study was based on the use of the Saarbergwerke coal liquefaction process to perform the primary liquefaction step. All subsequent processing was to be done using established, well defined processes. All potential technological problems were to be identified. The cost of producing a synthetic crude oil, suitable for an existing Canadian petroleum refinery, was to be estimated.

PROCEDURE

Western Canadian coal (sub-bituminous C) was shipped to Germany for processing by the Saarbergwerke Company (subcontractor) in their 5-kg/h bench-scale unit. Yields and suitable operating conditions were established. These feedstock qualities were used by process licensors to determine operating conditions and capital costs for all subsequent processors. Another subcontractor, Kilborn Alberta Ltd., developed an overall process flowsheet for all of the processes. They also produced a detailed flowsheet for the primary Saarbergwerke coal liquefaction process. Capital and operating costs were obtained. A third subcontractor, the Alberta Research Council, performed autoclave tests on a number of Western Canadian coals to indicate which coals were most suitable for coal liquefaction.

RESULTS

To achieve a project rate of return of 15%, a synthetic crude price of $50/barrel (1980) is required. It was assumed that the project would be financed by 100% equity capital. The total cost of a coal processing complex to produce 60,000 barrels/day of synthetic crude oil was found to be $3.5 billion (1980 $ Can.). The annual operating cost was $270.8 million. A permanent work force of 960 persons will be required to staff the complex. Conceptual flowsheets, stream material balances, process unit specifications and equipment data sheets were prepared. Thirteen coals were liquefied in autoclaves by Saarbergwerke and seven by the Alberta Research Council. Although the absolute values of the results were different, with one exception, the order of ranking the coals by both subcontractors was the same.

The 10 recommendations for additional work included several pilot plant studies. In addition, the use of larger scale processing equipment to evaluate the Saarbergwerke process and an examination of the following options: a direct contact coal slurry preheat system, synthesis gas instead of hydrogen, and the use of purge hydrogen, were recommended. A thorough experimental pilot plant study of secondary hydrotreating was considered essential prior to further development.

TITLE: TECHNICAL ASSESSMENT OF COAL LIQUEFACTION PROCESSES AS PART OF COST-SHARED COAL CONVERSION PROGRAM

				FUNDING	
CONTRACTOR:	Surveyer, Nenniger & Chenevert	FILE NUMBER:	9-9036		
		BEGIN/END:	Aug. 79/Aug. 80		
				CANMET:	$100,000
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	50,411
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	M. Ternan	TECHNOLOGY:	Liquefaction	TOTAL:	$150,411

OBJECTIVES

1. To determine current state-of-the-art technology and provide review update on 7 advanced coal liquefaction processes - SRC II, H-Coal, Exxon Donor Solvent, I.G. Farber, Flush Hydropyrolysis, Supercritical Gas Extraction, and Dow Chemical Catalytic Liquefaction.

2. To predict behaviour of Canadian coals in these processes based on previous experience of process developers in their tests with similar coals.

3. To identify major problems and technological uncertainties to be resolved before commercialization of these processes and to provide alternative solutions in an attempt to evaluate the technical risks.

4. To formulate research and development projects to open avenues of investigation that could profitably be carried out in Canada in support of the commercial development of these processes for Canada.

PROCEDURE

1. To assess the current state of development of each process.

2. To select the best process for each type of Canadian coal; bituminous, sub-bituminous and lignite.

3. To send samples of sub-bituminous coal to each process developer and have them provide yields.

4. To do material and energy balances around each piece of equipment for each process.

5. To identify the technical strengths and weaknesses of each process.

6. To identify areas in which research and development should be done in Canada to further the development of coal liquefaction technology.

RESULTS

A nine-volume report has been produced - one for each of the seven processes, one describing support systems common to all, and one containing a comparison of the processes.

Material and energy balances are given for each process. The amount of testing each developer has done is documented, giving types of coals tested at various scales, i.e., batch tests, bench tests, pilot-plant tests, and demonstration plants. Problems encountered at each operating scale are listed and the solutions found by the process developer are given. Areas requiring further research are listed.

The contract did not require any economic comparisons. However, a brief discussion of process economies and ranking of the processes is included.

TITLE: FEASIBILITY OF USING SUPERCRITICAL GAS EXTRACTION TECHNIQUES FOR LIQUEFACTION OF CANADIAN COALS

CONTRACTOR:	Raylo Chemicals Ltd.	FILE NUMBER:	8-9091	FUNDING	
		BEGIN/END:	Oct. 79/March 80		
				CANMET:	$35,990
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	A.E. George	TECHNOLOGY:	Liquefaction	TOTAL:	$35,990

OBJECTIVES

1. Design and construct a simple semi-continuous extraction system.
2. Extract samples of a specified coal and evaluate the effects of temperature, pressure, solvent and gas flowrate on the efficiency of extraction.
3. Define a standard set of parameters for extraction based on experimental results.
4. Apply the procedure for screening various coals.

PROCEDURE & RESULTS

A semi-continuous bench scale plant was constructed and commissioned. Samples of high-volatile bituminous C coal, sub-bituminous coal and lignite were extracted with supercritical toluene at 400°C and 1500 psig. The yields of extracted liquids were 17.1%, 13.7% and 15.4% respectively, on a dry weight basis. The non-caking free flowing chars remaining after extraction had higher calorific values on a dry basis than the coals from which they were derived. The calorific value of the chars from sub-bituminous coal was enhanced by 10.4% while that of the chars from lignite was enhanced by 15.7%.

APPLICATION AND ONGOING WORK

Another contract has been awarded to Raylo Chemicals, for the period from April 1980 to March 1981, to continue the work that was started in the first contract. The new contract covers the study of extraction variables (temperature, pressure and flowrate), solvents (reactive and inert), analyses (standard and special) and design studies if it is decided to go to higher scale operations.

TITLE: OPTIMIZATION, CHEMISTRY AND PRODUCT ANALYSIS OF SUPERCRITICAL GAS EXTRACTION TECHNIQUES FOR LIQUEFACTION OF CANADIAN COALS - CONTINUATION

CONTRACTOR:	Raylo Chemicals Ltd.	FILE NUMBER:	9-9169	FUNDING	
		BEGIN/END:	Apr. 80/Dec. 80		
				CANMET:	$86,180
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	A.E. George	TECHNOLOGY:	Liquefaction	TOTAL:	$86,180

OBJECTIVES

1. To provide data about the relative importance of pyrolytic and extraction processes in the Supercritical Gas (SCG) extraction of coal.
2. To evaluate the effects of temperature, pressure, solvent and flowrate on the efficiency of SCG extractions of various coals.
3. To investigate chemical interactions between toluene and pyrolysis generated intermediates during the SCG extraction of coal.
4. To provide analytical data on the coal liquefaction products obtained during optimized extraction conditions.

PROCEDURE

Two methods were developed for SCG extraction. Samples and solvent were heated in an autoclave. In Method A, operating pressure was maintained by releasing excess pressure, losing the solvent. In Method B, extra solvent was pumped into the system as excess pressure was released. Three litres of solvent was pumped through each system after operating temperature was reached. Experimental conditions were developed using toluene as solvent. Then various solvents were evaluated for SCG extraction.

Mathematical models of yield, solvent density and extraction efficiency were developed as a function of temperature, pressure and fluid density.

Petrographic, thermogravimetric, proximate and ultimate analysis and pyridine solubilities were performed on the coals and chars.

The Coal-Derived Liquid (CDL) products were analyzed by infrared, carbon-13 and proton magnetic resonance spectroscopy.

RESULTS

The yield of CDL by SCG extraction is dependent on the method used, temperature, pressure, flowrate of extracting gas and solvent used, toluene being better than paraffinic solvents. Oxygenated solvents undergo degradation, but may be useful as a reactive co-solvent for increasing CDL yield or upgrading CDL quality. Hydrogen donating solvents such as tetralin improve CDL yield and alter char characteristics. The chemical composition of CDL was sensitive to extraction temperature with an increase in aromaticity at high temperatures.

APPLICATION AND ONGOING WORK

Past work indicates that higher temperatures and pressures will increase the yield of liquids. The objectives are to build a bench-scale reactor with higher temperature and pressure capabilities and study CDL yields under these conditions. A study to determine the specific chemical and physical properties of an extraction solvent, by using pure solvent blends, is proposed in an effort to find a crude solvent suitable for extraction. This project will also provide data and recommendations to EMR to assess the economic potential of SCG extraction.

TITLE: SHORT RESIDENCE TIME FLASH PYROLYSIS OF COAL

CONTRACTOR:	University of Waterloo	FILE NUMBER:	8-9105-1	FUNDING	
		BEGIN/END:	Oct. 79/Apr. 80		
				CANMET:	$30,982
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J.F. Kelly	TECHNOLOGY:	Liquefaction	TOTAL:	$30,982

OBJECTIVES

1. To design and construct a reactor system patterned after that developed by CSIRO, Australia. It was to consist of a coal feeder suspended from a continuous weight loss recorder, a quartz miniature fluidized bed reactor, and a suitable product collection system. Feed rate of coal was to be 1-5 g/h.

2. To study the effect of reaction conditions on coal conversion and product yields. About 50 experiments were required covering temperatures from 550 to 750°C, residence times from 40 to 400 ms, two coal particle sizes, and using hydrogen and nitrogen as fluidizing gas.

3. Analysis and comparison of results to similar work elsewhere, and visits to other research centres where pyrolysis research was being conducted.

PROCEDURE

A miniature fluidized bed apparatus was constructed which works very successfully, covering temperatures from 400 to 800°C and residence times from 0.3 to 2.0 s. The limitation on residence times is not due to the reactor, but to inability to analyze dilute off-gases with sufficient accuracy. A successful low rate entrained flow pulverized coal feeder was developed which is capable of giving steady flow from 5 to 100 g/h in the present version, with coal to entrained gas weight ratios of up to 4:1. Its full capabilities for fine coal have not yet been assessed.

RESULTS

Objective 1 has been satisfactorily completed, and Objective 3 has been largely accomplished. A further four months of work is estimated necessary to achieve most of Objective 2. An outline of this further work has been submitted and a request for supplemental funding made. For more details, refer to final report.

TITLE: SHORT RESIDENCE TIME PYROLYSIS OF COAL - CONTINUATION

CONTRACTOR:	University of Waterloo	FILE NUMBER:	1-9032	FUNDING	
		BEGIN/END:	June 81/June 82		
				CANMET:	$25,952
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	S. Fouda	TECHNOLOGY:	Liquefaction	TOTAL:	$25,952

OBJECTIVES

1. To evaluate the behaviour of Canadian coals during atmospheric flash pyrolysis.

2. To update the state-of-the-art review of flash pyrolysis and hydropyrolysis research.

PROCEDURE

1. A bench-scale fluidized bed pyrolysis unit was utilized to carry out the pyrolysis runs on three Canadian coals, namely, Highvale sub-bituminous, Forrestburg sub-bituminous and Devco high-volatile bituminous. A total of 39 runs was carried out at various temperatures between 773-1023°K in various atmospheres (N_2, CO_2 & H_2).

2. Visits were made to several North American research institutes that are active in pyrolysis and hydropyrolysis areas. The state-of-the-art review was updated on the basis of these visits.

RESULTS

1. Yields from the flash pyrolysis of Highvale and Forrestburg coals were reported. Tar yields as high as 10% maf coal were obtained from Forrestburg and slightly higher yields were obtained from Highvale. Maximum liquid yields were obtained at 923°K.

2. Yields of gases were higher in the hydrogen atmosphere than in N_2 or CO_2.

3. Problems were encountered on running Devco coal; a new reactor design is needed to handle caking coals.

4. A more extensive screening program is needed to survey more coals at a wider range of process variables.

APPLICATION AND ONGOING WORK

This provides a database for the behaviour of Canadian coals during flash pyrolysis.

Requested an extension to continue the screening tests on a wider range of Canadian coals which would provide a database to assist in designing experiments using larger scale units.

TITLE: CHARACTERIZATION OF COAL DERIVED LIQUIDS

CONTRACTOR:	Raylo Chemicals Ltd.	FILE NUMBER:	9-9157	FUNDING	
		BEGIN/END:	March 80/May 82		
				CANMET:	$49,990
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	M.A. Poirier	TECHNOLOGY:	Liquefaction	TOTAL:	$49,990

OBJECTIVES

The characterization of coal liquids is of great importance for the development of coal liquefaction processes. Fast and effective methods for characterization of coal liquids are needed for the comparison of coal liquids of different origins as well as for the determination of the influence of changes in process parameters of the quality of the coal liquid produced.

PROCEDURE

1. Distillation
2. Separation into toluene soluble and insoluble material
3. Separation of the THF insolubles
4. Separation into oil and asphaltenes
5. Results of solvent analysis
6. Fractionation of asphaltenes
7. Liquid chromatography
8. NMR data for preasphaltene
9. FTIR analysis, THF insolubles, preasphaltene
10. Elemental analysis results
11. Molecular weight determination

RESULTS

Coal liquids are, in general, very complex mixtures of different groups of compounds of varied molecular weight and composition. Types of data used for the characterization of coal liquids include: proportions of oils; asphaltenes and residues; elemental analysis of the main fractions; molecular weight determination; identification of the main families' compounds; and distribution of the aliphatic and aromatic carbons.

APPLICATION AND ONGOING WORK

Methods developed in this work, as well as the results, will be used for future in-house projects on characterization of coal liquids.

TITLE: CHARACTERIZATION OF SOLID RESIDUES FROM COAL LIQUEFACTION PROCESSES

CONTRACTOR:	University of Regina	FILE NUMBER:	9-9177	FUNDING	
		BEGIN/END:	Apr. 80/March 81		
				CANMET:	$54,382
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J. Price	TECHNOLOGY:	Liquefaction	TOTAL:	$54,382

OBJECTIVES

1. To investigate microscopically the feed materials and residues generated by CANMET contractors in the coal liquefaction program. Residuals analyzed microscopically came from studies of the hydrogenation of various coal ranks with heavy oils, bitumen, and anthracine oil; the reduction, and then liquefaction of coal; and the supercritical gas extraction of coal.

2. To characterize the origin of solid phases in the residues using optical and scanning electron microscopes.

3. To correlate results with experimental data and assess their effects on conversion.

PROCEDURE

Samples were prepared for optical analyses according to ASTM procedures. Reflectance measurements were recorded and qualitative analyses were performed on feedstocks using ICCP techniques. Residual particles were classified, firstly, according to whether they were isotropic or anisotropic and then further subdivided according to morphological character.

RESULTS

Residues from various processing methods were petrographically different. Those produced from the co-processing of coal with heavy oil or bitumen at 703°K contained more highly altered anisotropic semi-cokes and isotropic chars than those produced at 653°K. Liquid yields tended to decrease with semi-coke formation. Higher rank coals produced more semi-coke than lignites; this was minimized when excess hydrogen and catalysts were used. Upon supercritical gas extraction of coal with toluene, residues from hv coal had more vesiculated and altered chars than did lower rank coals. Coals were petrographically altered most with tetralin/toluene mixtures. Reduction of coal prior to liquefaction reduced grain size; reduced coal softened and reacted forming isotropic residues containing little anisotropic semi-coke.

APPLICATION AND ONGOING WORK

Microscopic characterizations of the source and nature of the materials that do not liquefy in CANMET sponsored liquefaction projects are being continued at the University of Regina in 81/82. Such studies are essential for a better understanding of coal liquefaction and for optimizing conversion.

TITLE: DESIGN OF CONCEPTUAL HEATING PLANT INCORPORATING EXISTING BOILERS AND NEW FLUIDIZED BED BOILERS AT SUMMERSIDE, P.E.I. - PHASE 2

CONTRACTOR:	Foster Wheeler Ltd.	FILE NUMBER:	8-9036	FUNDING	
		BEGIN/END:	Dec. 78/June 79		
				CANMET:	$109,371
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	F.D. Friedrich	TECHNOLOGY:	Combustion	TOTAL:	$109,371

OBJECTIVES

The overall objectives of the Summerside Fluid Bed Project are:

1. Demonstrate fluidized bed combustion (FBC) as a viable means of burning coal in a heating plant boiler.
2. Demonstrate FBC of high-sulphur coal in a limestone bed as an economical and practical alternative to flue gas scrubbing as a means of controlling SO_2 emissions.
3. Demonstrate the use of wood chips as a supplementary fuel to coal in an FBC boiler.
4. Transfer foreign FBC technology to at least two Canadian suppliers.

Objectives of present contract:

1. To develop a conceptual design of addition to CFB Summerside's heating plant No. 2 which would accommodate two fluidized bed boilers.
2. Obtain cost estimate for such extension.

PROCEDURE

A 6-phase program has been developed as follows:

1. Conceptual design of a fluidized bed boiler.
2. Conceptual design of a heating plant to accommodate two FBC boilers.
3. Detailed design and cost proposal of a heating plant addition with one FBC boiler.
4. Construction of a heating plant addition with one FBC boiler.
5. Testing and demonstration of FBC boiler with a range of coals and other solid fuels.
6. Procurement of second FBC boiler.

All work is being carried out by contract and to meet Objective 4, Phases 1, 2 and 3 are being carried out by two competing contractors. The present contract is one of two let for Phase 2. The contractor prepared a conceptual plant design to meet requirements stipulated by DND and EMR.

RESULTS

The conceptual plant design covers an extension to existing CHP No. 2, with space for two FBC boilers at 18 000 kg/h of steam each. In-plant storage of coal, limestone and ash is sufficient for 96 h at a demand rate of 25 000 kg/h. Controls for the two existing boilers and the two proposed FBC boilers are integrated into a single control room. Construction schedule and cost estimate were prepared. Feasibility of co-generation was investigated. Strategy and cost estimate were developed for retrofitting a stoker to the FBC boiler should tests prove FBC to be an unsatisfactory technology for this application. A program, time schedule and cost estimate were prepared for testing and demonstrating the performance of the FBC boiler after erection.

APPLICATION AND ONGOING WORK

The present contract is one of two for Phase 2 of the Summerside Fluid Bed Project.

TITLE: CONCEPTUAL HEATING PLANT DESIGN AND BOILER DEMONSTRATION PROGRAM FOR DEPARTMENT OF NATIONAL DEFENCE BASE, SUMMERSIDE, P.E.I. - PHASE 2

CONTRACTOR:	Intercontinental Engineering Ltd.	FILE NUMBER:	8-9037	FUNDING	
		BEGIN/END:	March 79/Sept. 79		
				CANMET:	$160,772
CANMET SCIENTIFIC		ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	F.D. Friedrich	TECHNOLOGY:	Combustion	TOTAL:	$160,772

OBJECTIVES

The overall objectives of the Summerside Fluid Bed Project are:

1. Demonstrate fluidized bed combustion (FBC) as a viable means of burning coal in a heating plant boiler.
2. Demonstrate FBC of high-sulphur coal in a limestone bed as an economical and practical alternative to flue gas scrubbing as a means of controlling SO_2 emissions.
3. Demonstrate the use of wood chips as a supplementary fuel to coal in an FBC boiler.
4. Transfer foreign FBC technology to at least two Canadian suppliers.

Objectives of present contract:

1. To develop a conceptual design of addition to CFB Summerside's heating plant No. 2 which would accommodate two fluidized bed boilers.
2. Obtain a cost estimate for such extension.

...OCEDURE

A 6-phase program has been developed as follows:

1. Conceptual design of a fluidized bed boiler.
2. Conceptual design of a heating plant to accommodate two FBC boilers.
3. Detailed design and cost proposal of a heating plant addition with one FBC boiler.
4. Construction of a heating plant addition with one FBC boiler.
5. Testing and demonstration of FBC boiler with a range of coals and other solid fuels.
6. Procurement of second FBC boiler.

All work is being carried out by contract and to meet Objective 4, Phases 1, 2 and 3 are being carried out by two competing contractors. The present contract is one of two let for Phase 2. The contractor prepared a conceptual plant design to meet requirements stipulated by DND and EMR.

RESULTS

The conceptual plant design covers an extension to existing CHP No. 2, with space for two FBC boilers at 18 000 kg/h of steam each. In-plant storage of coal, limestone and ash is sufficient for 96 h at a demand rate of 25 000 kg/h. Controls for the two existing boilers and the two proposed FBC boilers are integrated into a single control room. Construction schedule and cost estimate were prepared. Feasibility of co-generation was investigated. Strategy and cost estimate were developed for retrofitting a stoker to the FBC boiler should tests prove FBC to be an unsatisfactory technology for this application. A program, time schedule and cost estimate were prepared for testing and demonstrating the performance of the FBC boiler after erection.

APPLICATION AND ONGOING WORK

The present contract is one of two for Phase 2 of the Summerside Fluid Bed Project.

TITLE: ASH DISPOSAL FOR THE DEPARTMENT OF NATIONAL DEFENCE BASE, SUMMERSIDE, P.E.I.

CONTRACTOR:	Intercontinental Engineering Ltd.	FILE NUMBER:	8-9037-1	FUNDING	
		BEGIN/END:	July 79/Sept. 79	CANMET:	$51,390
CANMET SCIENTIFIC AUTHORITY:	J. Robert	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Combustion	TOTAL:	$51,390

OBJECTIVES

To investigate the potential quantities, composition and disposal methods and/or utilization of the solid bed waste material and fluidized combustion ash (FCA) from the proposed fluidized bed combustor at CFB Summerside and to recommend further areas for examination.

PROCEDURE

1. A literature review of existing FCA utilization methods and characterization of potential problems.
2. Liaison with provincial and industrial representatives to establish their concerns and investigate potential marketable value of FCA.
3. Field investigation of disposal sites and establishing further environmental/geological criteria.

RESULTS

1. A report listing possible environmental concerns.
2. Disposal method, suitable sites and further test work required on final site selection.

APPLICATION AND ONGOING WORK

Pending site selection for disposal area.

TITLE: PILOT PLANT TRIALS OF FLUIDIZED BED COMBUSTION USING MARITIME COAL, SUMMERSIDE, P.E.I.

CONTRACTOR: Foster Wheeler Limited		FILE NUMBER:	9-9010	FUNDING	
		BEGIN/END:	July 79/Nov. 79		
				CANMET:	$83,692
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY: F. Friedrich		TECHNOLOGY:	Combustion	TOTAL:	$83,692

OBJECTIVES

The overall objectives of the Summerside Fluid Bed Project are:

1. Demonstrate fluidized bed combustion (FBC) as a viable means of burning coal in a heating plant boiler.
2. Demonstrate FBC of high-sulphur coal in a limestone bed as an economical and practical alternative to flue gas scrubbing as a means of controlling SO_2 emissions.
3. Demonstrate the use of wood chips as a supplementary fuel to coal in an FBC boiler.
4. Transfer foreign FBC technology to at least two Canadian suppliers.

The objectives of the present contract are to conduct pilot-scale tests with the design fuels and sulphur sorbent for CFB Summerside to determine:

1. Combustion efficiency of the design coal and the demonstration coal.
2. Effectiveness of the design limestone as a sulphur sorbent.
3. Combustion performance when co-firing the design coal and wood chips.

The results are to form the technical basis for one of two full-scale designs.

PROCEDURE

The Summerside project is organized into six phases of which Phase 3, carried out during 1980, consists of detailed design and firm price proposal of a complete heating plant equipped with one FBC boiler. Two suppliers have been contracted to prepare competing designs. The present contract is in support of one of the Phase 3 contracts.

The contractor obtained samples of the design fuels and sorbent and subcontracted the pilot-scale tests to its parent firm, Foster Wheeler Corp. in Livingston, New Jersey. Approximately 250 h of pilot-scale test work was carried out in a 129-cm^2 FB combustor. Detailed measurements of material flows, combustion parameters and pollutant emissions were made. A comprehensive report was prepared and submitted.

RESULTS

1. Both the design coal and demonstration coal could be burned at acceptable levels of combustion efficiency.
2. Better than 85% sulphur removal was readily achieved using the design limestone at Ca/S ratios of less than 3:1.
3. Elutriation rate of ash and sorbent is high and in order to maintain bed level it may not be possible to reduce Ca/S ratio much below 3:1.
4. Co-firing of coal and wood chips appears to be feasible.

APPLICATION AND ONGOING WORK

The present contract constitutes work in support of Phase 3 of the Summerside Fluid Bed Project.

TITLE: DETAILED DESIGN OF A FLUIDIZED BED HEATING PLANT, CFB SUMMERSIDE, P.E.I. - PHASE 3

CONTRACTOR:	Foster Wheeler Limited	FILE NUMBER:	9-9011	FUNDING	
		BEGIN/END:	Feb. 80/Jan. 81		
				CANMET:	$425,000
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	F. Friedrich	TECHNOLOGY:	Combustion	TOTAL:	$425,000

OBJECTIVES

The overall objectives of the Summerside Fluid Bed Project are:

1. Demonstrate fluidized bed combustion (FBC) as a viable means of burning coal in a heating plant boiler.
2. Demonstrate FBC of high-sulphur coal in a limestone bed as an economical and practical alternative to flue gas scrubbing as a means of controlling SO_2 emissions.
3. Demonstrate the use of wood chips as a supplementary fuel to coal in an FBC boiler.
4. Transfer foreign FBC technology to at least two Canadian suppliers.

The objectives of the present contract are:

1. To develop a detailed design for a complete heating plant incorporating two fluidized bed boilers, which would be an addition to the existing No. 2 plant at CFB Summerside.
2. To obtain a firm price quotation for the subject FBC heating plant.

PROCEDURE

A 6-phase program has been developed as follows:

1. Conceptual design of fluidized bed boiler.
2. Conceptual design of heating plant to accommodate two FBC boilers.
3. Detailed design and cost proposal of heating plant addition with one FBC boiler.
4. Construction of heating plant addition with one FBC boiler.
5. Testing and demonstration of FBC boiler using a range of coals and other solid fuels.
6. Procurement of second FBC boiler.

All work is being carried out by contract and to meet Objective 4, Phases 1, 2 and 3 are being carried out by two competing contractors. The present contract is one of two let for Phase 3. The contractor prepared a detailed design to meet requirements stipulated by DND and EMR, and submitted a firm price proposal for building it.

RESULTS

Foster Wheeler's detailed design was carefully compared with the competing design from Dominion Bridge, resulting in Foster Wheeler being awarded a construction contract for approximately $13 million. Scheduled completion is December 1982. It was decided to purchase both boilers at the same time, thus eliminating Phase 6.

APPLICATION AND ONGOING WORK

A contract for Phase 4 - Construction - has been let as noted above. A work statement for Phase 5 - Testing and Demonstration - will be prepared by the end of 1982.

TITLE: FLUIDIZED BED COMBUSTOR FOR A COAL DRYER

CONTRACTOR:	Luscar Limited	FILE NUMBER:	9-9067	FUNDING	
		BEGIN/END:	Feb. 80/Oct. 80		
				CANMET:	$ 35,000
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	70,000
SCIENTIFIC		SUB-ACTIVITY:	Coal	DORR-OLIVER	
AUTHORITY:	F. Friedrich	TECHNOLOGY:	Combustion	CANADA LTD.:	10,000
				TOTAL:	$115,000

OBJECTIVES

1. To determine the technical feasibility of burning coal washery rejects in an atmospheric fluidized bed combustor (FBC) to replace clean coal in an existing coal drying plant and to replace propane in an existing coal preparation plant heating system.

2. To develop a conceptual design and cost estimate for a full-scale FBC burning washery rejects with a heat input of approximately 73 $MW_{(th)}$.

3. To determine the economic feasibility of the proposed full-scale demonstration.

PROCEDURE

1. Dorr-Oliver Canada Ltd. were sub-contracted to conduct pilot-scale tests with the coal washery rejects and to prepare a conceptual design and cost estimate for the full-scale process equipment. It was found that the rejects were readily burned but an elaborate system for gas clean-up was required. Full-scale process equipment was estimated to cost approximately $10 million.

2. Luscar Ltd. prepared a detailed estimate for erection of process equipment, construction of a building, and supply of ancillary equipment for materials handling, heat distribution, etc. This amounted to an additional $12 million.

3. Luscar then carried out an economic analysis to determine the payback period on the required investment.

RESULTS

The project, at a total cost of $22 million, was found to have a payback period of approximately double that normally acceptable for industrial investment, thus it is not economically feasible at present.

A comprehensive report was prepared.

APPLICATION AND ONGOING WORK

The approach may be economical at other sites. Luscar is continuing R & D to determine whether technical requirements can be reduced thus reducing costs, and to determine the economics of proceeding with a smaller system to provide plant heating only.

TITLE: TECHNICAL AND ECONOMIC ASSESSMENT OF A COAL/ OIL SLURRY FIRING SYSTEM ON A UTILITY BOILER

CONTRACTOR:	New Brunswick Electric Power Commission	FILE NUMBER:	7-9055-4	FUNDING	
		BEGIN/END:	June 78/March 79	CANMET:	$248,420
CANMET SCIENTIFIC AUTHORITY:	H. Whaley	ACTIVITY:	Energy Technology	CONTRACTOR:	248,420
		SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Combustion	TOTAL:	$496,840

OBJECTIVES

To continue COM combustion evaluation in a small utility boiler and to evaluate an oil agglomeration coal beneficiation process in COM preparation and handling.

1. Evaluate the performance of improved burner tips and pumps specially selected for handling a COM of Minto, N.B. coal and No. 6 fuel oil.
2. Investigate environmental emissions and fly ash distribution when firing COM and compare these to those from oil firing.
3. Demonstrate whether on-line mixing of coal agglomerates in oil is adequate for power plant operation.
4. Investigate the different heat-absorbing characteristics of the furnace when firing COM.
5. Evaluate the performance of an oil agglomeration process designed to remove ash and sulphur components from the coal.
6. Determine the economics of the modified fuel preparation plant as it is related to increased power and light oil consumption.
7. Determine the constraints and limitations of the process and develop refinements as appropriate.

PROCEDURE & RESULTS

1. Developed a conceptual design for the incorporation of the NRC coal/oil agglomeration process into the fuel preparation system for Chatham, GS #1 boiler [10 MW(e)].
2. Finalized the design of the coal/oil agglomeration process and equipment and planned for its connection to the firing system.
3. Conducted preliminary bench-scale tests of agglomeration and subsequent slurry preparation before installation of process components.
4. Installed the coal/oil agglomeration process equipment and slurry component systems and carried out commissioning trials. These trials may be carried out separately for the individual elements.
5. Carried out tests with respect to the redispersion of the agglomerated fuel particles in hot residual oil.
6. Trained operating personnel and at the same time conducted preliminary combustion tests and made any required modifications to the system.
7. Carried out a 12-week full-scale combustion trial of the entire system (800 h total operation). During this period the performance and environmental aspects of the process were evaluated.
8. Prepared a final report.

APPLICATION AND ONGOING WORK

This work is being continued and will increase the mass per cent coal content of the COM fuel and further evaluate the coal agglomeration process under operating conditions.

TITLE: TECHNICAL AND ECONOMIC ASSESSMENT OF A COAL-IN-OIL SLURRY FIRING SYSTEM ON A UTILITY BOILER

CONTRACTOR:	New Brunswick Electric Power Commission	FILE NUMBER:	8-9125-3	FUNDING	
		BEGIN/END:	Apr. 79/March 80	CANMET:	$202,329
CANMET SCIENTIFIC AUTHORITY:	H. Whaley	ACTIVITY:	Energy Technology	CONTRACTOR:	202,329
		SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Combustion	TOTAL:	$404,658

OBJECTIVES

To continue operation of a small utility boiler on a Coal/Oil Mixture (COM) and to evaluate an on-line COM preparation system utilizing coal cleaning.

1. Evaluate the existing coal-oil agglomeration system and make modifications to improve the COM supply system.
2. Investigate the effect of light oil emulsification on the coal-oil agglomeration process and to substitute heavy fuel oil for light oil in the process.
3. Select and assess burners suitable for COM firing.
4. Increase the coal content of the COM to 40% *m/m*.
5. Prepare a proposal for conversion of a larger [100 MW(e)] unit to COM.

PROCEDURE & RESULTS

1. Major parts of the COM supply system were redesigned to incorporate a new ball mill and hydroshear emulsifier. Operation of the system to achieve satisfactory COM supply prior to the tests.
2. Existing modified CEA insert burners and new CPC "Y" jet burners tested on No. 6 fuel oil prior to COM tests.
3. Preliminary COM trials and commissioning of COM supply system.
4. Operation at 30-40% *m/m* coal in COM. Operational difficulties with burner tip wear caused delays, therefore, burner materials development incorporated as a secondary objective. Achieved 800 h of operation by April 1980. Objective of 1400 h curtailed by abrasive wear of burner tips.
5. Preliminary proposal for conversion of Dalhousie #1 [100 MW(e)] made by NBEPC.

APPLICATION AND ONGOING WORK

Abrasive wear of burner tips identified as a major problem in the utilization of COM technology. Because of the expense of overcoming this using the Chatham unit, this problem is being addressed at the Ontario Research Foundation in a Burner Wear Evaluation Program (Feb. 1981-present). A program of demonstration of coal-water technology is in the early planning stages.

This research ties in with Canada's active role under the IEA coal-liquid mixtures technology interchange agreement.

TITLE: SURVEY AND EVALUATION OF BURNER DESIGNS FOR COAL-LIQUID MIXTURE COMBUSTION

				FUNDING	
CONTRACTOR:	Technical University of Nova Scotia, Centre for Energy Studies	FILE NUMBER:	1-9075		
		BEGIN/END:	Oct. 81/Feb. 82	CANMET:	$11,000
				CONTRACTOR:	--
CANMET SCIENTIFIC AUTHORITY:	H. Whaley	ACTIVITY:	Energy Technology	OTHER:	--
		SUB-ACTIVITY:	Coal	TOTAL:	$11,000
		TECHNOLOGY:	Combustion		

OBJECTIVES

1. To collect information on industrial oil burners available in the North American and European markets.
2. To ascertain the performance of oil burners on coal-liquid mixtures (CLM).
3. To critically examine testing procedures for nozzles using CLM.
4. To prepare a report on the above activities.

PROCEDURE

1. Contact major North American and European burner manufacturers for design information.
2. Obtain details of any test or development work which has been conducted on CLM.
3. Critically review such information and comment on the applicability of such information to the Canadian CLM Program.

RESULTS

1. The major companies were contacted and the relevant information compiled.
2. Test methods for CLM nozzle development were reviewed.
3. The final report was received by CANMET in February 1982.

APPLICATION AND ONGOING WORK

1. The information is useful in CANMET's continuing support of CLM atomizer development as well as for generally describing industrial oil burning equipment.
2. A nozzle development program is being conducted at Scotia-Liquicoal in Dartmouth, Nova Scotia.

TITLE: BEHAVIOUR OF COAL PARTICULATES SUBJECTED TO COMPACTION PRESSURES UP TO 2000 PSI

CONTRACTOR:	Warnock Hersey Professional Services Ltd.	FILE NUMBER:	0-9088	FUNDING	
		BEGIN/END:	Jan. 81/March 81	CANMET:	$10,800
CANMET SCIENTIFIC AUTHORITY:	D. Desai	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Combustion	TOTAL:	$10,800

OBJECTIVES

1. To form coal plugs or compacts by subjecting coal to various compaction pressures up to 2000 psi (13.8 MPa) in a bench-scale static testing device, using two size consists, three moisture levels and two lengths of coal plugs.

2. Measure air permeability of the coal plugs at various supply air pressures.

3. Blowout tests on compacts after some of the compaction tests.

PROCEDURE

Coal samples of two size consists (fine and coarse) and three moisture levels were used. The compaction mould consisted of sample cylinder, the top and bottom pistons and blowout helmet. The coal sample was poured into the cylinder over the bottom piston. A Rhiele loading press was used to carefully apply the required pressure through contact with the top piston.

The air permeability measuring set up was attached and compressed air was supplied at the bottom of the cylinder. The airflow through the sample, at various supply air pressures, was measured with a flowmeter.

After some tests, blowout tests were attempted on the sample by supplying air at higher pressures.

RESULTS

1. Increase in compaction pressure resulted in decrease in airflow through the sample.

2. Air permeability increases as the applied air pressure increases.

3. The higher the water content, the lower is the air permeability, and zero air permeability can be achieved.

4. Air permeability is lower with finer coal.

5. With smaller length of samples, the air permeability was lower in many tests.

6. No unique relationship between the air permeability and compaction stress, void ratio, or dry density was observed although there are trends.

APPLICATION AND ONGOING WORK

Feeding coal and other low compressibility raw material into pressure vessels such as a pressurized fluid bed or pressurized gasifier.

Demonstration of a coal feeder for such application.

TITLE: TRACE CONTAMINANT STUDY AT COAL-FIRED POWER PLANTS

				FUNDING	
CONTRACTOR:	Canadian Electrical Association	FILE NUMBER:	0-9141		
		BEGIN/END:	Nov. 80/Nov. 82		
				CANMET:	$ 50,000
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	500,000
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER (EC):	20,000
AUTHORITY:	G.K. Lee	TECHNOLOGY:	Combustion	TOTAL:	$570,000

OBJECTIVES

1. To co-fund a study of trace element emissions from two Canadian coal-fired power plants with the Canadian Electrical Association and Environment Canada.

2. To identify, to the degree possible, the pathways for release of trace elements from coal burning.

3. To measure the distribution of the trace elements in each pathway.

PROCEDURE

1. Literature review of trace element releases and analytical methods to be used.

2. Field sampling of fuel, ash and flue gas at Battle River and Lingan Generating Stations.

3. Analyze and characterize field samples according to organic, inorganic and radionuclide content.

4. Environmental sampling around Battle River of trace element receptors including soil, water and biota.

5. Final report on above is not part of the CANMET contract for work which ended on March 31, 1982. It will be available to CANMET from the Canadian Electrical Association in 1982/83 under CEA Project G194.

RESULTS

Raw data on Procedures 1 to 4 are given in a Battelle interim report dated March 31, 1982 to the Canadian Electrical Association.

APPLICATION AND ONGOING WORK

Evaluation of data is in progress. The final report is not due until 1984 when the entire CEA program is completed on four plants.

TITLE: LOW NO_x TECHNICO-ECONOMIC STUDY - PHASE 1

CONTRACTOR: G.A. Robb		FILE NUMBER:	1-9119	FUNDING	
		BEGIN/END:	Jan. 82/May 82		
CANMET				CANMET:	$15,000
SCIENTIFIC		ACTIVITY:	Energy Technology	CONTRACTOR:	--
AUTHORITY: G.K. Lee		SUB-ACTIVITY:	Coal	OTHER:	--
		TECHNOLOGY:	Combustion	TOTAL:	$15,000

OBJECTIVES

1. Review and evaluate Energy and Environmental Research Corp. (EER) contract recommendations.
2. Evaluate low-NO_x, low-SO_x burner technologies.
3. Identify constraints of existing equipment on burner retrofitting.
4. Summarize availability and cost of potential low-NO_x burners with compatible additive injection systems.

PROCEDURE

1. Conduct a technico/economic assessment of the findings of the EER study on low-NO_x burner development.
2. Assemble technical data on proven low-NO_x burner concepts with SO_2 neutralization.
3. Conduct an assessment of local limestone supplies.
4. Conduct plant visits and interview staff to determine performance and geometry of existing equipment.

RESULTS

1. EER study recommendations deemed uneconomic and too complex for requirements.
2. Limestone availability identified and costed.
3. Space and equipment limitations at CFB Gagetown identified and recorded.
4. Four international firms recommended as being competent and experienced enough to undertake the required work - Steinmuller GmbH, B. & W., C.E. (Canada), and Foster Wheeler Energy Corp.

APPLICATION AND ONGOING WORK

Work has entered Phase 2 and a second contract was let to G.A. Robb to prepare a test report on baseline data for incorporation into an RFP for retrofitting one unit at CFB Gagetown.

TITLE: DETERMINATION OF RHEOLOGICAL PROPERTIES OF COAL-OIL SLURRIES

CONTRACTOR:	Saskatchewan Research Council	FILE NUMBER:	7-9073-7	FUNDING	
		BEGIN/END:	March 78/March 79		
				CANMET:	$35,425
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G.N. Banks	TECHNOLOGY:	Slurry Transport	TOTAL:	$35,425

OBJECTIVES

To obtain sufficient experimental rheological data on selected coal-oil mixtures to be able to undertake the design of transfer pipelines for potential coal gasification plants and combustion equipment to be utilized in Canada. In addition to conventional oils, samples of bitumen, pitch and heavy gas-oil from oil-sands processing plants were to be investigated as diluents with the selected coal samples.

PROCEDURE

1. Three coal samples - Sparwood metallurgical refuse coal from British Columbia, Sheerness sub-bituminous coal from Alberta and Estevan lignite coal from Saskatchewan - were selected as suitable coals for investigation.

2. Samples of No. 2 and No. 6 fuel oils were obtained from Imperial Oil's Strathcona refinery and samples of bitumen, pitch and heavy gas-oil were supplied by EMR to be used as diluents.

3. Four size ranges of each coal were used at varying slurry concentrations over a suitable range of temperatures.

4. Preliminary determinations of slurry viscosities were obtained in a Brookfield Model LV Syncro-Letric viscometer at temperatures up to 265°C. A vertical tube viscometer, constructed by Saskatchewan Research Council, was used to obtain further data on slurry viscosities and pressure drops at room temperature.

5. A variable temperature vertical tube viscometer was designed and constructed to operate at temperatures up to 300°C.

RESULTS

1. Viscosity data were developed for the various diluents and slurries up to 265°C using the Brookfield viscometer.

2. Pressure gradient curves were developed for various slurry ranges in No. 2 fuel (25 to 55 *m/m* of coal) at room temperature using the vertical tube viscometer.

3. Mechanical problems with the new high temperature vertical tube viscometer proved to be overwhelming and prevented this section of the project (using the more viscous diluents) from being completed. It is planned to carry out extensive modifications to the viscometer and to complete the rheology study once the rig is operating satisfactorily.

4. Final report received in May 1981.

APPLICATION AND ONGOING WORK

The rheological data obtained in this project can be usefully applied in developing designs for coal-oil slurry transfer lines.

ENERGY TECHNOLOGY

NUCLEAR ENERGY

TITLE: MINE CAPITAL AND OPERATING COST ESTIMATES

CONTRACTOR:	Wright Engineers Ltd.	FILE NUMBER:	8-9106	FUNDING	
		BEGIN/END:	May 79/Dec. 79		
				CANMET:	$4,000
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Nuclear Energy	OTHER:	--
AUTHORITY:	R.J.R. Welwood	TECHNOLOGY:	Resource & Reserve Assessment	TOTAL:	$4,000

OBJECTIVES

To develop individual mine capital and operating cost estimates for selected potential uranium mining operations. These are to be used by MRL's Mine Evaluation Group in determining cut-off grades for uranium reserve assessment, as well as in evaluating potentially economic uranium deposits in Canada. Both activities are required for EMR's Uranium Resource Appraisal Group (URAG).

PROCEDURE

The scientific authority supplied the contractor with a completed questionnaire containing essential input parameters for each of four potential mining operations. The contractor utilized his own computer programs to obtain a complete summary printout of estimated capital costs for each. In addition to the estimates of capital costs, the contractor supplied estimates of mine operating costs. The operating cost estimates were subjective engineering judgements based on the considerable relevant experience of the contractor's staff.

RESULTS

To fulfill contract requirements, the contractor submitted three sets of correspondence to the Scientific Authority during 1979: July 27, Nov. 29 and Dec. 14. These constituted satisfactory report equivalents comprising complete computer summary printouts of capital costs, plus summary estimates of mine operating costs. Results are judged to be quite satisfactory.

APPLICATION AND ONGOING WORK

These estimates are of direct value in the economic evaluation of relevant Canadian uranium deposits by MRL's Mine Evaluation Group.

TITLE: MINE EVALUATION TECHNIQUES

CONTRACTOR:	Dames & Moore	FILE NUMBER:	8-9107	FUNDING	
		BEGIN/END:	June 79/March 80	CANMET:	$26,560
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Nuclear Energy	OTHER:	--
AUTHORITY:	R.J.R. Welwood	TECHNOLOGY:	Resource & Reserve Assessment	TOTAL:	$26,560

OBJECTIVES

1. To evolve optimal standard economic evaluation techniques, suitable for evaluating economic and/or potentially economic uranium deposits in Canada on a common basis. Such systems must be capable of determining the economic viability of deposits in typical Canadian situations, for any given return on investment.

2. To compile a suitable manual and supply relevant computer programs.

PROCEDURE

The contractor was instructed to commence a literature survey, from which an interim report would evolve assessing the relative merits of various mine economic evaluation techniques. Then he was advised to select at least two established techniques most suitable as standard mine evaluation procedures for application to individual deposits. The principal activity was the preparation of a descriptive manual, containing adequate examples of applications. A final comprehensive report was required, incorporating the standard practice manual.

Computer programs were to be developed for evaluation studies and supplied to CANMET's Mine Evaluation Group with adequate indoctrination regarding their use.

RESULTS

Two principal procedures were selected and described, with examples, in a final report, which also included notes and examples on many facets of economic evaluation.

Computer programs were developed, with descriptions included in the final report. Contractor's representative spent some time in the Ottawa offices of CANMET's Mine Evaluation Group for indoctrination of staff in their application and use.

TITLE: MINE CAPITAL AND OPERATING COST MODELS

CONTRACTOR: Dames & Moore	FILE NUMBER:	8-9124	FUNDING	
	BEGIN/END:	Sept. 79/Oct. 80		
			CANMET:	$32,812
CANMET	ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY:	Nuclear Energy	OTHER:	--
AUTHORITY: R. Welwood	TECHNOLOGY:	Resource & Reserve Assessment	TOTAL	$32,812

OBJECTIVES

1. To establish mine capital and operating cost models suitable for mining situations anywhere in Canada.

2. Specifically, to construct frameworks of cost components for significant activities and sub-activities, suitable for various types of mining and milling operations. These must be designed to store cost input data, to accept modifications on a unit basis and to deliver cost estimates in desired standard formats.

3. To establish related computer programs and indoctrinate CANMET's Mine Evaluation Group staff in their application and use.

PROCEDURE

1. Construct computer models for unit cost inputs, storage and retrieval for specific production situations.

2. Assemble cost data for these situations and provide computer listings to illustrate computer program applications for them.

3. Compile a report describing the generalities involved and the computer programs.

4. Provide debriefing in Ottawa for CANMET's Mine Evaluation Group.

RESULTS

Contractor assembled many useful cost figures and related computer programs for specific situations. The latter have since been modified for general application. Contractor also provided a brief general descriptive report, which included the specific cost figures for unique situations, as well as descriptions of the associated computer programs. A representative visited the Ottawa offices of CANMET's Mine Evaluation Group to indoctrinate its staff in the application and use of these computer programs.

TITLE: DESIGN AND PROCUREMENT OF A CONTINUOUS ION EXCHANGE PILOT PLANT FOR THE TREATMENT OF URANIUM LEACH LIQUOR

CONTRACTOR:	Wright Engineers Ltd.	FILE NUMBER:	8-9033	FUNDING	
		BEGIN/END:	Nov. 78/Nov. 79		
				CANMET:	$37,305
CANMET		ACTIVITY:	Energy Technology	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Nuclear Energy	OTHER:	--
AUTHORITY:	B.H. Lucas	TECHNOLOGY:	Processing of Radioactive Ores	TOTAL:	$37,305

OBJECTIVES

To design a continuous ion exchange pilot plant and procure the necessary equipment.

PROCEDURE

Wright Engineers Ltd. were given the design parameters and the layout of the 5 cm diam, 0.5 L/min flow, CANMET Laboratory CIX model by the Scientific Authority (S.A.). A 100 L/min CIX pilot plant was designed and modified by consultation between Wright and the S.A. Tenders were let for the fabrication or purchase of equipment by Wright Engineers. Companies were selected by DSS and the S.A. and purchases were made by Wright who had delivery made to Eldorado Hangar, Edmonton, Alberta. The S.A. inspected the equipment before delivery to Beaverlodge, Sask. Wright Engineers inspected the CIX pilot plant installation thus completing the contract.

RESULTS

The pilot plant was successfully commissioned and the operation has been quite satisfactory.

APPLICATION AND ONGOING WORK

The CIX pilot plant is being used to extract uranium from mine water. Test work is being carried out to optimize the process parameters and obtain design data.

TITLE: EVALUATION OF CHLORINE/CHLORIDE BASED PROCESSES FOR URANIUM ORES

CONTRACTOR:	The Lummus Co. Canada Limited	FILE NUMBER:	9-9130	FUNDING	
		BEGIN/END:	May 80/Sept. 80	CANMET:	$32,000
CANMET SCIENTIFIC AUTHORITY:	W.A. Gow	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Nuclear Energy	OTHER:	--
		TECHNOLOGY:	Processing of Radioactive Ores	TOTAL:	$32,000

OBJECTIVES

Concern over acid drainage and radionuclide dissolution problems associated with uranium tailings disposal has prompted investigations into improved methods of isolating uranium, thorium and radium from tailings. Several processes to overcome these problems and produce tailings more suitable for disposal have been proposed.

The primary purpose of this study was to develop order of magnitude capital and operating costs for two processes now being considered by CANMET to reduce the radioactive content of mill tailings. The cost information is intended to assist CANMET in selecting areas deserving further study.

PROCEDURE

The C.E. Lummus Minerals Division was commissioned by the Department of Supply and Services to evaluate "Chlorine/Chloride Based Processes for Uranium Ores". The processes are designed to remove substantially all radioactive constituents from the ores to render the waste products harmless. Lummus engineers followed the general outline contained in their proposal.

Experimental work carried out at EMR's CANMET laboratories in Ottawa was used as a basis for the evaluation.

At a meeting between CANMET engineers and scientists and Lummus engineers on May 27, 1980, agreement was reached on the processes to be investigated and CANMET provided Lummus with technical literature and laboratory data. Two processes were selected, one for a typical low grade ore (2 lb U_3O_8/ton ore) and one for a high grade ore (50 lb U_3O_8/ton ore). For the low grade ore, a hydrochloric acid leaching process was chosen. For high grade ore, a more complex process, including gaseous chlorination, was selected.

A second meeting was held to present Lummus' preliminary process flow diagrams and to incorporate comments from CANMET scientists and engineers. When the process flow diagrams were completed, they were used to generate major equipment specifications, utility diagrams and plot plans for each process.

Capital cost estimates were compiled from information obtained from vendors for the specified equipment. The building cost estimates and the piping, electrical and instrumentation costs were developed from the plant layout.

Utility diagrams and mass balances were used for estimating utilities and consumables.

RESULTS

An evaluation of the capital and operating costs of two plants using chlorine/chloride technology to produce yellowcake from uranium ores has been made. The results are given below:

Ore Grade	Low Grade	High Grade
U_3O_8 Content of Ore: lbs/ton	2.0	50
Ore Input: tons/day	5 200	200
U_3O_8 Production: lbs/day	10 000	10 000
lbs/year	3 300 000	3 300 000
Process Used:	Hydrochloric Acid Leach	Chlorination & Hydrochloric Acid Leach
Direct Capital Cost: $	138 800 000	67 000 000
$/annual lb U_3O_8	42.06	20.30
Direct Operating Cost: $/year	22 540 000	14 050 000
$/ton ore	13.13	213.00
$/lb U_3O_8	6.83	4.26

APPLICATION AND ONGOING WORK

The data will be compared with information being developed in-house on cost of conventional processes to determine future direction and potential of chlorine-based processes for uranium ore.

ENERGY TECHNOLOGY

RENEWABLE ENERGY

TITLE: DEVELOPMENT OF SODIUM SOLID ELECTROLYTE CERAMICS AND EVALUATION OF THEIR SUITABILITY FOR ENERGY CONVERSION AND STORAGE DEVICES

CONTRACTOR:	Sinclair Radio Laboratories Ltd.	FILE NUMBER:	8-9115	FUNDING	
		BEGIN/END:	March 79/Sept. 81		
				CANMET:	--
CANMET SCIENTIFIC AUTHORITY:	T. Wheat	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Renewable Energy	OTHER (DSS):	$ 89,756
		TECHNOLOGY:	Materials for Advanced Energy Conversion Systems	(NRC):	151,450
				TOTAL:	$241,206

OBJECTIVES

1. To develop optimized sodium ion conductors: beta-alumina, beta"-alumina and zirpsios.

2. To design, construct and demonstrate a thermoelectric generator that exploits the materials developed.

PROCEDURE

The company sub-contracted materials development to Ontario Research Foundation, Dept. Ceramics. Company seconded a staff member to ORF for the duration of the contract. Generator designed by company and constructed by ORF.

RESULTS

1. Contractor developed the three materials and demonstrated that one particular composition for the beta"-alumina is far superior to any reported to date.

2. Contractor exceeded requirements of contract by constructing two thermoelectric generators; one a flat-plate design, the other a closed-tube design.

3. Contractor demonstrated that conversion efficiency was within 95% of that reported by the Ford Motor Co. for a related device.

4. All contract requirements met within duration of contract and slightly under budget.

APPLICATION AND ONGOING WORK

Materials development work and generator design to be continued under PILP support. It is intended to demonstrate a device recovering energy from company's stack gases.

TITLE: CHARACTERIZATION OF THREE-DIMENSIONAL FAST-ION ELECTROLYTES USING NUCLEAR MAGNETIC RESONANCE ANALYSIS

CONTRACTOR:	Queen's University	FILE NUMBER:	0-9076	FUNDING	
		BEGIN/END:	Jan. 81/March 82	CANMET:	$12,413
CANMET SCIENTIFIC AUTHORITY:	T.A. Wheat	ACTIVITY:	Energy Technology	CONTRACTOR:	--
		SUB-ACTIVITY:	Renewable Energy	OTHER:	--
		TECHNOLOGY:	Materials for Advanced Energy Conversion Systems	TOTAL:	$12,413

OBJECTIVES

To determine the correlation between the ionic conductivity of various sodium-ion conducting solid electrolytes and their NMR spectra.

PROCEDURE

The ionic conductivity of a number of materials was determined using classical methods and compared with the signatures obtained from NMR data.

RESULTS

The correlations that exist between NMR and ionic conductivity were shown to be material specific - no generalized correlation was established that is applicable for all materials.

Of the various materials studied (beta-aluminas, Na-zirpsios [x = 1.8 to 2.4], $Na_5YSi_4O_{12}$ and $Na_5GdSi_4O_{12}$), it was found that the beta-aluminas (both the Na^+ and H_3O^+ forms) could be rapidly characterized by NMR and the data correlated well with microstructural and conductivity changes in this group of materials. Similarly, differences in the Na-zirpsios shown by NMR could be correlated with changes in structure and conductivity; essentially no correlation was found for the $Na_5YSi_4O_{12}$ and $Na_5GdSi_4O_{12}$.

APPLICATION AND ONGOING WORK

The strong correlation between NMR signatures and conductivity in the beta-aluminas suggests that a rapid, non-contacting method of indirectly determining the ionic conductivity of these materials can be developed, suitable for production-line purposes, using an imbalanced rf bridge. Such a system would be invaluable in quality control.

OPINION POLL

The opinion of concerned readers may influence the direction of future CANMET research.

We invite your assessment of this report - No._____

Is it useful?	Yes_____	No_____
Is it pertinent to an industry problem?	Yes_____	No_____
Is the subject of high priority?	Yes_____	No_____

Comments_____

_____

_____

Please mail to: CANMET Editor, EMR, 555 Booth Street,
Ottawa, Ontario, K1A 0G1

A complimentary copy of the CANMET REVIEW describing CANMET research activity will be sent on request.

CANMET REPORTS

Recent CANMET reports presently available or soon to be released through Printing and Publishing, Supply and Services Canada (addresses on inside front cover), or from CANMET Publications Office, 555 Booth Street, Ottawa, Ontario, K1A 0G1:

Les récents rapports de CANMET, qui sont présentement disponibles ou qui le seront bientôt peuvent être obtenus de la direction de l'Imprimerie et de l'Edition, Approvisionnements et Services Canada (adresses au verso de la page couverture), ou du Bureau de Vente et distribution de CANMET, 555 rue Booth, Ottawa, Ontario, K1A 0G1:

80-26E Release of Lead from typical Canadian Pottery glazes; D.H.H. Quon and K.E. Bell;
Cat. No. M38-13/80-26E, ISBN 0-660-10902-6; Price: $1.75 Canada, $2.10 other countries.

80-27E Generation and control of mine airborne dust; G. Knight;
Cat. No. M38-13/80-27E, ISBN 0-660-10958-1; Price: $2.10 Canada, $2.50 other countries.

81-1E Niobium ore OKA-1 - A certified reference material; H. Steger and W.S. Bowman;
Cat. No. M38-13/81-1E, ISBN 0-660-10915-8; Price: $1.75 Canada, $2.10 other countries.

81-2E Acid extraction of alumina from Canadian non-bauxite sources at CANMET; Colin Hamer;
Cat. No. M38-13/81-2E, ISBN 0-660-10957-3; Price: $2.00 Canada, $2.40 other countries.

81-3E Feasibility study on recovery of thermal coal from waste dumps in Nova Scotia; M.W. Mikhail, L.C. Bird and N.T.L. Landgren;
Cat. No. M38-13/81-3E, ISBN 0-660-11007-5; Price: $3.75 Canada, $4.50 other countries.

81-4E Effect of Pore Size in MoO_3-CaO-Al_2O_3 Hydrocracking Catalysts; A.H. Hardin, H. Ternan and R.H. Packwood;
Cat. No. M38-13/81-4E, ISBN 0-660-11065-2; Price: $3.75 Canada, $4.50 other countries.

81-5E High performance liquid chromatographic method for type analysis of hydrocarbons in synthetic fuel naphtha; J.E. Beshai and A.E. George;
Cat. No. M38-13/81-5E, ISBN 0-660-10985-9; Price: $1.50 Canada, $1.80 other countries.

81-7E DH1a: A certified uranium-thorium - Reference ore; H. Steger and W.S. Bowman;
Cat. No. M38-13/81-7E, ISBN 0-660-11046-6; Price: $2.00 Canada, $2.40 other countries.

81-8E Mineralogy of the Caribou massive sulphide deposit, Bathurst area, New Brunswick; J.L. Jambor;
Cat. No. M38-13/81-8E, ISBN 0-660-11128-4; Price: $4.75 Canada, $5.70 other countries.

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